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ORIGINAL

PINHOLE TEST EQUIPMENT DESIGN AND TEST RESULT EVALUATION

June 1985

Engineering and Research Center

U. S. Department of the Interior

Bureau of Reclamation

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16. ABSTRACT

A revised design for the USBR (Bureau of Reclamation) pinhole test apparatus has been developed and evaluated at the Engineering and Research Center and two regional project laboratories. Modifications to the equipment have simplified the procedures for placing specimens, determining placement density, conducting the test, and interpreting the test results. Project laboratories performed 407 pinhole and crumb tests for USBR project-feature investigations and construction control. The flow-rate data from these pinhole tests have been evaluated and used to refine the original pinhole test dispersive grade versus flow-rate criteria.

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b. IDENTIFIERS-- McGee Creek Dam/ Central Arizona Project/

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PINHOLE TEST EQUIPMENT DESIGN AND TEST RESULT EVALUATION

by

Raymond G. Acciardi

June 1985

Geotechnical Branch
Division of Research and Laboratory Services
Engineering and Research Center
Denver, Colorado

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CONTENTS

Page

Introduction 1

Summary and conclusions 1

Development of original USBR pinhole test apparatus 1

Field evaluation of USBR pinhole test apparatus 4

Results of field laboratory pinhole and crumb tests 7

Evaluation of pinhole test flow-rate data 7

Bibliography 14

Appendix

A – Red Rocks Pumping Plant 17
B – Brady Pumping Plant 18
C – Tucson Aqueduct – reach 2 19
D – Tucson Aqueduct – reach 3 22
E – Cliff Dam – downstream area 24
F – Tucson Aqueduct – reach 1 25
G – Tucson Aqueduct – reach 1 borrow area 27
H – Miscellaneous specimens – Nos. 4 and 10 comparison tests 30
I – McGee Creek Dam – lime-treated soil in borrow area F 31
J – McGee Creek Dam – stockpiled lime-treated soil 37
K – USBR 5410-XX, Procedure for Determining the Dispersibility of Clayey Soils by the Pinhole Test Method 39
L – USBR 5400-XX, Procedure for Determining the Dispersibility of Clayey Soils by the Crumb Test Method 63
M – Flow-rate data summaries – ND3, ND2, and ND1 soils 74

TABLES

Table

1 Summary of dispersive grades (field test data) 8
2 Pinhole test and crumb test data correlation 8

FIGURES

Figure

1 Pinhole test dispersive grade versus flow rate 2
2 USBR pinhole test apparatus – original design 3
3 USBR pinhole test apparatus – modified design (2 sheets) 5
4 Dispersive grade versus frequency of occurrence 9
5 Flow-rate data versus frequency of occurrence (3 sheets) 10

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INTRODUCTION

The pinhole test was originally developed during the early 1970's, by Dr. James L. Sherard to provide qualitative information on soil erosion resistance to flowing water. Until that time, it had been recognized that some clayey soils naturally and readily deflocculate, or disperse, in the presence of water. The physico-chemical characteristics of the colloidal clay particle and water system were recognized as the primary variables involved in soil dispersion. However, quantitative chemical test methods were known to have limitations as standard laboratory tests for identifying dispersive soils. The work of early researchers investigating soil dispersion [1, 2, 3]* resulted in simple qualitative methods for indirectly assessing soil dispersion. The indirect test methods of Volk and Emerson, later popularized as the double hydrometer test and the crumb test, respectively, were well known to soil scientists and agricultural engineers, but relatively unknown to geotechnical and civil engineers. Sherard used these tests to corroborate pinhole tests and pore-water chemistry data on soils with erosion characteristics that were known from field performance. In 1976, Sherard's pinhole test [4] became the first qualitative physical test in which the soil's erosion resistance to flowing water was directly observed during the test.

SUMMARY AND CONCLUSIONS

The results of 407 pinhole and crumb tests are summarized in the appendix. These data were obtained from the first USBR field evaluations conducted for the identification, classification, and construction control of dispersive soils. USBR project laboratories at the McGee Creek damsite in Farris, Oklahoma, and the Central Arizona Project in Phoenix, Arizona, were provided equipment, and personnel were trained to conduct and interpret pinhole, crumb, and double hydrometer tests. Liaison between the field project laboratories and the E&R (Engineering and Research) Center laboratory staff ensured that field testing and data analysis resulted in correct identification and classification of dispersive and nondispersive soils. All field test data show that the pinhole and crumb tests can be conducted easily and reliably at construction project laboratories when proper training and followup data analyses are provided.

Figure 1 shows criteria for dispersive grade classification versus flow rate and was developed from several hundred individual pinhole tests. The classification boundary zones provide a 95-percent confidence level for correctly classifying soil dispersive grades using pinhole test flow-rate data.

* Numbers in brackets refer to the Bibliography.

DEVELOPMENT OF ORIGINAL PINHOLE TEST APPARATUS

Concurrent with Sherard's pinhole test investigations in the early 1970's, Dr. Haliburton of Oklahoma State University, in cooperation with the USBR, developed the physical erosion test. The physical erosion test equipment, test procedure, and soil test results were documented in 1975 [5]. The original USBR pinhole test apparatus was developed from 1975 to 1977. Because both the pinhole and the physical erosion tests were new state-of-the-art soil-dispersion identification tests, the original USBR pinhole test apparatus was designed to be compatible with the physical erosion test apparatus. The pinhole specimen cylinders and cylinder end plates were identical with those used in the physical erosion test. Special pinhole specimen packing plugs were designed to account for the shorter pinhole specimen. Figure 2 shows the original USBR pinhole test apparatus.

From 1975 to 1977, both the pinhole and physical erosion tests were evaluated using soils from miscellaneous USBR project features. This trial evaluation resulted in the adoption of the pinhole test as the preferred USBR laboratory test for identifying dispersive soils.

The development of the original USBR pinhole test apparatus and test procedure was based on Sherard's paper [4] and documented in 1979, by James L. Kinney [6]. A significant difference between the USBR and the Sherard pinhole apparatus was the use of a 2.2-mm-diameter hole in the truncated cone centering guide (nipple) of the USBR apparatus. The Sherard pinhole apparatus has a 1.5-mm hole. Appendix A of Kinney's report [6] explains why the hole in the nipple was enlarged to 2.2 mm to achieve the system flow rates published in Sherard's paper [4].

The USBR pinhole apparatus with the enlarged nipple hole was used from March 1977 until July 1981. During this period, several problems were experienced using the original USBR design of the pinhole apparatus [6] and Sherard's pinhole test evaluation criteria [4]:

1. The minimum hydraulic cross section of the USBR pinhole apparatus (2.2-mm diameter) was significantly greater than Sherard's pinhole apparatus (1.5-mm diameter), resulting in different flow rates at the same hydraulic head [7].

2. The effluent turbidity criteria were difficult to interpret and introduced operator bias in arriving at final dispersive-grade classifications [7].

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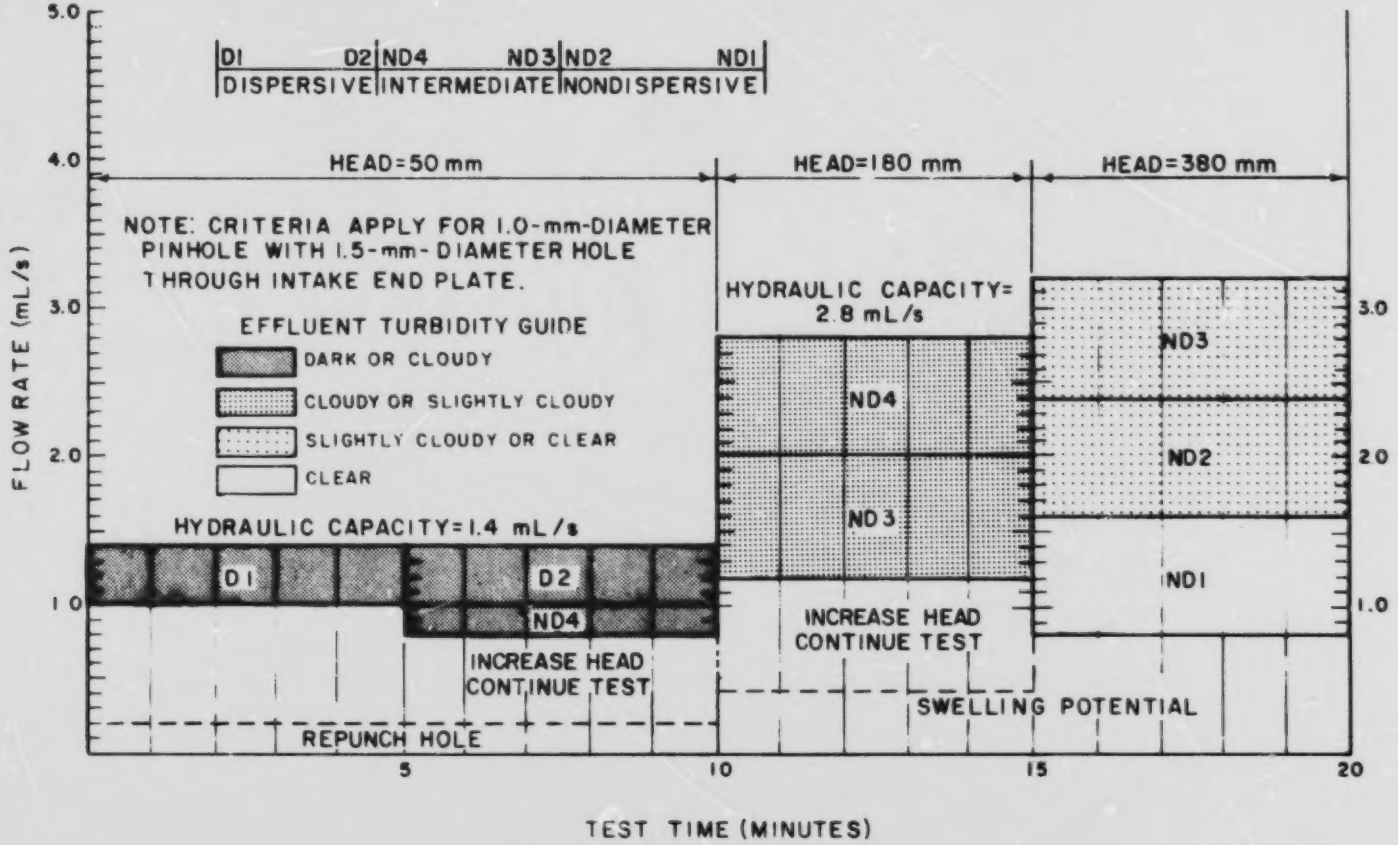

DISPERSIVE GRADE VS FLOW RATE

SAMPLE NUMBER	PLACEMENT CONDITIONS		DISPERSIVE GRADE CLASSIFICATION
	DRY DENSITY	WATER CONTENT	

Figure 1. – Pinhole test dispersive grade versus flow rate.

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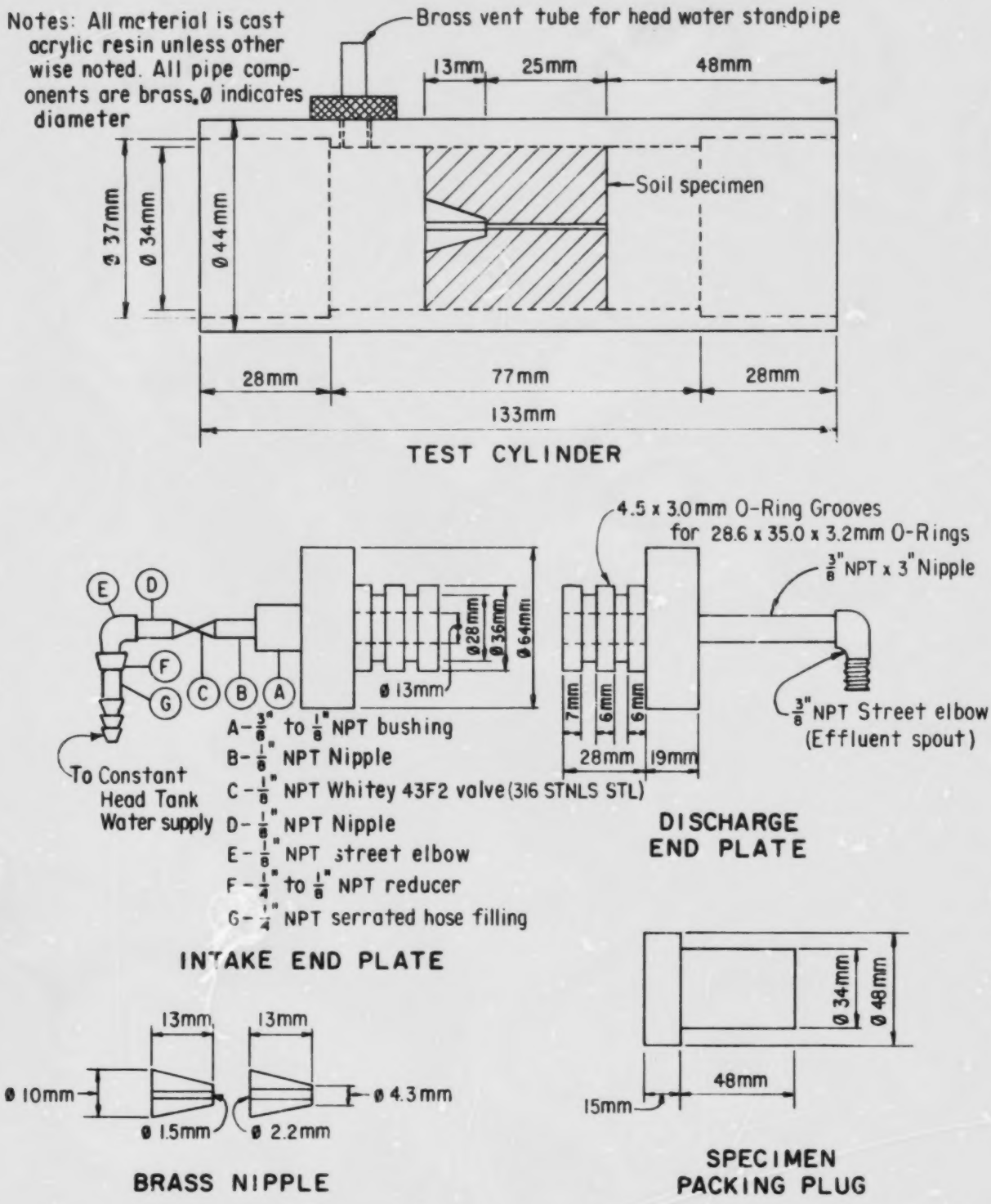

Figure 2. – USBR pinhole test apparatus – original design.

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3. Evaluation of measured flow rates appeared to be a reasonable, technically sound approach for arriving at dispersive-grade classifications, but preliminary investigations showed problems (appendix A of [6]).

The problem areas identified above were resolved as the result of extensive investigations conducted from July 1981 through January 1982. Several significant results of those investigations are fully documented in reference [7] and briefly summarized below:

1. Equipment design problems were identified with Sherard's original pinhole apparatus and caused the actual hydraulic head on the test specimen to be greater than the nominal hydraulic head.

2. When Sherard's flow-rate data were adjusted to correct the actual and nominal hydraulic head, it was found that flow-rate data could be used to accurately reclassify dispersive soils that had originally been classified on the basis of effluent turbidity.

3. Based on 1 and 2 above, the use of the 2.2-mm-diameter nipple hole was discontinued in July 1981, and the 1.5-mm-diameter nipple hole was reinstated for use in the USBR pinhole apparatus.

4. Dispersive-grade versus flow-rate criteria were developed using Sherard's original data and routine pinhole tests conducted at the USBR E&R Center laboratories. The pinhole test dispersive-grade versus flow-rate criteria were originally published as figure 15 of reference [7].

FIELD EVALUATION OF USBR PINHOLE TEST APPARATUS

In February 1980, a dispersive-clay field testing program was discussed and formalized for material investigation and construction control of project features of McGee Creek Dam, near Farris, Oklahoma. The details of that testing program are contained in reference [8]. The pinhole test apparatus shown on figure 2 was initially used at the field project laboratory. The procedures outlined in reference [6] and supplemental information contained in reference [8] were used by field laboratory personnel for conducting pinhole and crumb tests.

References [9, 10, 11] document the results of visits to the McGee Creek project laboratory from March 1981 to May 1982. During the field evaluation of the original pinhole test apparatus, several operating difficulties were identified:

1. The length of the test specimen cylinder, in relation to its diameter and the location of the soil specimen in the cylinder, hindered access from each open end. The specimen location made it difficult to properly position and insert the nipple centering guide for punching the pinhole.

2. The specimen compaction procedure required placing a known mass of moist soil to a predetermined final lift thickness and compacting this soil using impact-type compaction. Determining the final placement density was difficult because surface irregularities in the final compacted surface affected the average specimen length measurement.

3. The specimen conditioning procedure required a minimum of 16 hours curing in the test cylinder after compaction. This requirement was originally specified in reference [6] to ensure uniform moisture distribution in the test specimen before testing. This overnight curing requirement posed a problem for field construction control when the construction schedule required daily decisions based on pinhole test results.

4. The glass beads used upstream and downstream of the soil specimen were awkward to work with and required special handling when the pinhole specimen needed to be repunched before or during the test.

5. Inserting the nipple with the 1.5-mm-diameter hole caused local densification of the test specimen in the area immediately adjacent to and downstream of the nipple. There was no way to quantify the effect of the local densification resulting from inserting the nipple; however, eliminating the nipple simplified handling the specimen.

Figure 3 shows the USBR pinhole test apparatus with design modifications made to resolve the problem areas noted during the field-trial evaluation of the original pinhole test apparatus. This new pinhole test apparatus produces the same results as the original design with the following advantages:

1. The new pinhole specimen mold contains only the cylindrical soil specimen required for the test. This eliminates the problem of limited access to the specimen and allows the final placement density to be determined directly using conventional measurement techniques.

2. The new specimen compaction mold was designed to be compatible with commercially

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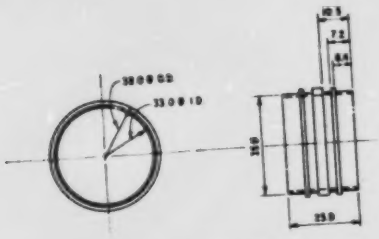
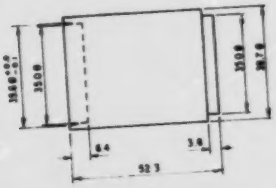
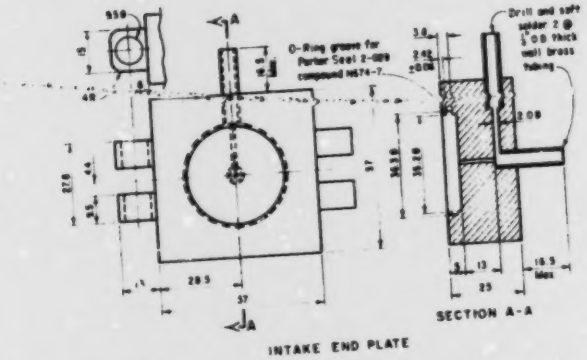


PINHOLE SPECIMEN MOLD

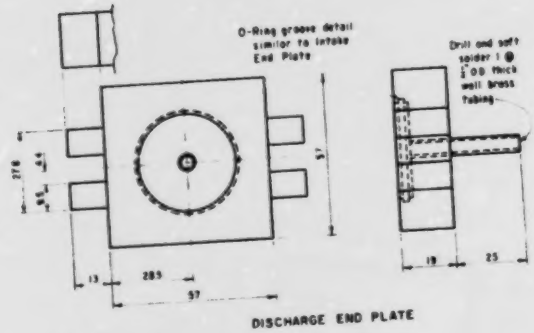


SPECIMEN MOLD ADAPTER

NOTES:
1. All dimensions are in millimeters.
2. Ø indicates diameter.
3. Stainless steel stock required.
4. Specimen Mold Adapter is designed for use with Soiltest, Inc. Part No. CN 428. Mold Holder. The adapter allows the Standard Hevard Miniature Compaction Mold Holder (CN 428) to be used with the USBR Pinhole Specimen Mold.



INTAKE END PLATE



DISCHARGE END PLATE

NOTES:
1. All dimensions are in millimeters.
2. Ø indicates diameter.
3. Brass stock required.

Figure 3. – USBR pinhole test apparatus – modified design (sheet 1 of 2).

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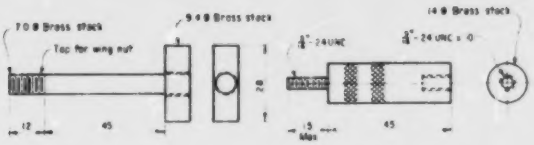
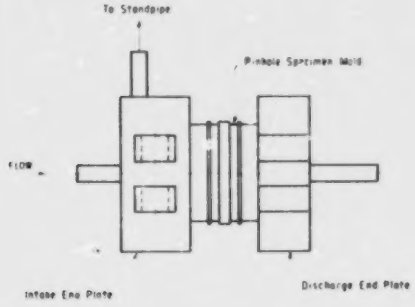
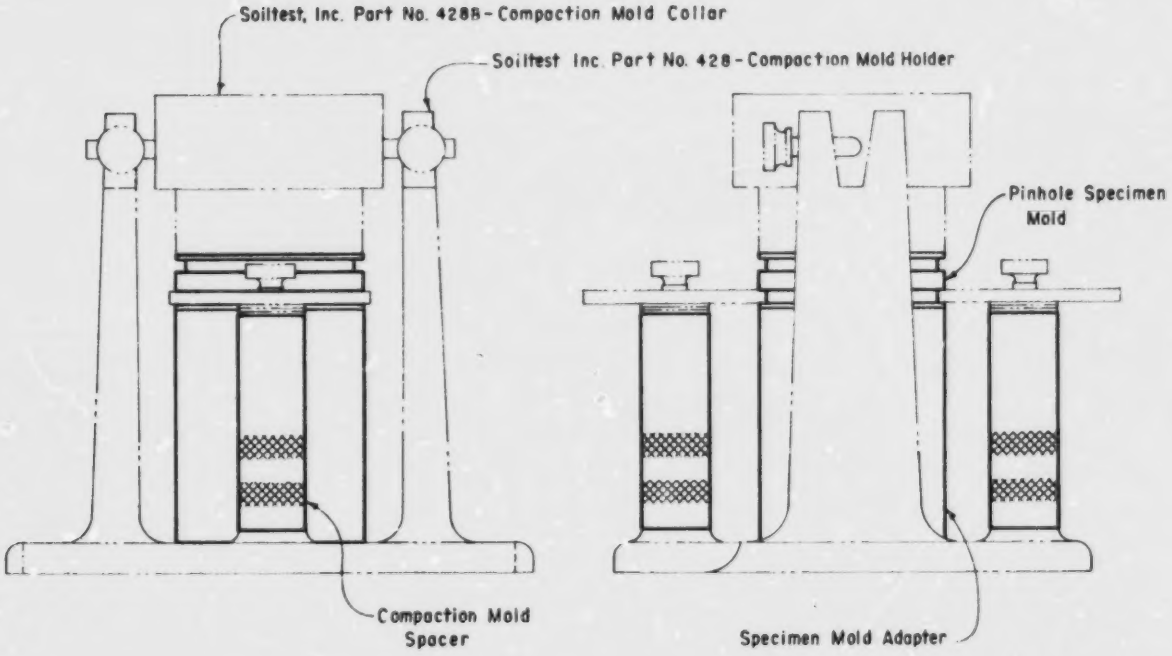


WING NUT & BOLT ASSEMBLY
(END PLATE CLAMPING DEVICE)

COMPACTION MOLD SPACER



PINHOLE TEST APPARATUS - ASSEMBLY DRAWING
(WING NUT & BOLT ASSEMBLY OMITTED FOR CLARITY)


Soiltest, Inc. Part No. 428B - Compaction Mold Collar
Soiltest Inc. Part No. 428 - Compaction Mold Holder
Pinhole Specimen Mold
Compaction Mold Spacer
Specimen Mold Adapter

PINHOLE SPECIMEN COMPACTION APPARATUS - ASSEMBLY DRAWING
(COMMERCIALLY AVAILABLE ITEMS SHOWN IN PHANTOM LINES)

Figure 3. – USBR pinhole test apparatus – modified design (sheet 2 of 2).

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available Harvard miniature compaction equipment, which uses a spring-loaded tamper. Specimens compacted with the spring-loaded tamper are more uniform than those prepared using impact type compaction.

3. The nipple centering guide with the 1.5-mm-diameter hole has been eliminated. The 1.5-mm-diameter hole has been incorporated in the equipment intake end plate.

4. The equipment end plates are connected directly to the upstream and downstream faces of the specimen. This eliminates the use of glass beads and greatly reduces the effort required to disassemble the apparatus to repunch the specimen pinhole.

5. The requirement to cure compacted specimens 16 hours before testing has been eliminated. The 16-hour curing requirement was originally specified to allow dissipation and equalization of excess pore pressures resulting from the compaction process, before performing the test. It was originally thought that the dispersion of clay colloids might be adversely affected by excess pore-water pressures. However, further analysis indicated that the physicochemical forces responsible for dispersion were considerably greater than the interparticle forces resulting from the compaction process. The uniform distribution of moisture throughout the specimen is ensured by allowing the specimen to mellow in the loose state before compaction. The test is conducted immediately after compacting the specimen.

Field evaluation of the modified design pinhole test apparatus began at the McGee Creek Project laboratory in June 1982. Another field laboratory evaluation program began at the Central Arizona Project laboratory at Phoenix, Arizona, in May 1983.

RESULTS OF FIELD LABORATORY PINHOLE AND CRUMB TESTS

Appendixes A through J contain detailed summary pinhole and crumb test results conducted on 407 soil specimens selected from various project features at the McGee Creek damsite and the Central Arizona Project. The pinhole and crumb tests were conducted using the detailed test procedures described in appendixes K and L, respectively. The dispersive grade classifications and correlation of the pinhole and crumb test results are given in table 1 and on figure 4.

Table 2 shows the pinhole test dispersive-grade classifications corroborated with the crumb test dispersive-grade classifications. Dispersive grades from both the pinhole and crumb test results are categorized individually and in groups. The 407 individual data sets are assumed to be a representative data base because all field test data received are included. The distribution of dispersive (27.7 percent), intermediate (13.8 percent), and nondispersive (58.5 percent) specimens, as classified by the pinhole test, and dispersive (23.3 percent) and nondispersive (76.7 percent) specimens, as classified by the crumb test, are also considered representative.

The data shown in table 2 confirm several important observations of pinhole and crumb test correlations that previously have been reported in the literature [4, 12, 13, 14]:

1. In the pinhole test, the majority of specimens showed either dispersive or nondispersive reactions; intermediate reactions seldom occurred (56 out of 407 cases).

2. The crumb test classifies dispersive soils with greater reliability than it classifies nondispersive soils. Of the soils tested, 31 percent showed a grade 1 or 2 (nondispersive) crumb test reaction along with a D1 or D2 (dispersive) reaction in the pinhole test. Only 4.2 percent of the crumb tests showed grades 3 or 4 dispersive reaction when the pinhole test showed ND2 or ND1 (nondispersive) reactions (10 out of 238 cases). This confirms that a soil has a high probability of being dispersive if the crumb test indicates dispersion.

3. If ND4 soils (intermediate) are included with D1 and D2 dispersive soils, and the ND3 soils (intermediate) are included with ND2 and ND1 soils, the crumb test correlations are not significantly changed. Of the crumb tests, 36 percent showed grade 1 or 2 (nondispersive reactions) when the pinhole test showed dispersive reactions. Three percent of the crumb tests showed grade 3 or 4 (dispersive) reactions when the pinhole test showed nondispersive reactions. This confirms that a nondispersive reaction in the crumb test does not reliably indicate that the soil is nondispersive.

EVALUATION OF PINHOLE TEST FLOW-RATE DATA

Appendix M contains a detailed summary of all 273 ND3, ND2, and ND1 pinhole test flow-rate data at heads at 50, 180, and 380 mm. As previously stated

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Table 1. – Summary of dispersive grades (field test data).

Project feature and data source		D1				D2				ND4				ND3				ND2				ND1		
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Red Rocks Pumping Plant (app. A)	23	4	–	2	–	–	1	1	–	–	–	–	–	4	1	–	–	–	–	–	–	10	–	–
Brady Pumping Plant (app. B)	15	–	–	2	1	–	–	3	1	–	–	2	1	–	–	1	–	–	–	–	–	3	1	–
Tucson Aqueduct – R2 (app. C)	56	–	1	1	–	3	3	–	–	5	–	–	–	5	–	–	–	1	–	–	–	33	4	–
Tucson Aqueduct – R3 (app. D)	30	2	2	2	–	–	–	1	–	–	1	–	–	3	–	1	–	3	–	–	–	15	–	–
Cliff Dam D/S (app. E)	14	1	–	1	–	–	1	1	–	–	–	–	–	7	–	–	–	–	–	–	–	3	–	–
Tucson Aqueduct – R1 (app. F)	47	–	4	23	3	–	–	8	–	2	–	–	–	1	–	–	–	–	–	–	–	6	–	–
Tucson Aqueduct – R1 Borrow Area (app. G)	68	2	5	10	–	2	4	4	1	2	–	1	–	6	1	–	–	1	–	1	–	27	1	–
Misc. specimens (– No. 10 and 4) (app. H)	3	1	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Lime treated soil McGee Creek Borrow Area F (app. I)	147	–	–	2	4	–	–	4	2	1	–	2	2	5	–	1	–	14	2	1	–	103	–	5
Lime treated – stockpiled soil (app. J)	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	3	–	–
All data	407	10	12	43	8	5	9	22	4	11	2	5	3	31	2	3	–	20	2	2	–	203	6	5

Table 2. – Pinhole test and crumb test data correlation

Pinhole test		Crumb test results (total percent specimens)							
Class	Number of specimens	1	2	3	4	1,2	3,4	1	2,3,4
D1	73	14	16	59	11	30	70	14	86
D2	40	12	22	55	11	34	66	12	88
ND4	21	53	10	24	13	63	37	53	47
D1,D2	113	13	18	58	11	31	69	13	87
D1,D2,ND4	134	19	17	52	12	36	64	19	81
ND3	35	86	5.7	8.3	0	92	8	86	14
ND2	24	83	8.5	8.5	0	92	8	83	17
ND1	214	95	2.8	2.2	0	98	3	95	5
ND1,ND2	238	44	3.4	2.6	0	97	3	94	6
ND1,ND2,ND3	273	93	3.7	3.3	0	97	3	93	7
D1,D2,ND4,ND3	169	33	15	43	9	48	52	33	67
ND4,ND3,ND2,ND1	294	90	4	5	1	94	6	90	10
ND4,ND3	56	73	7.1	14	5.9	80	20	73	27

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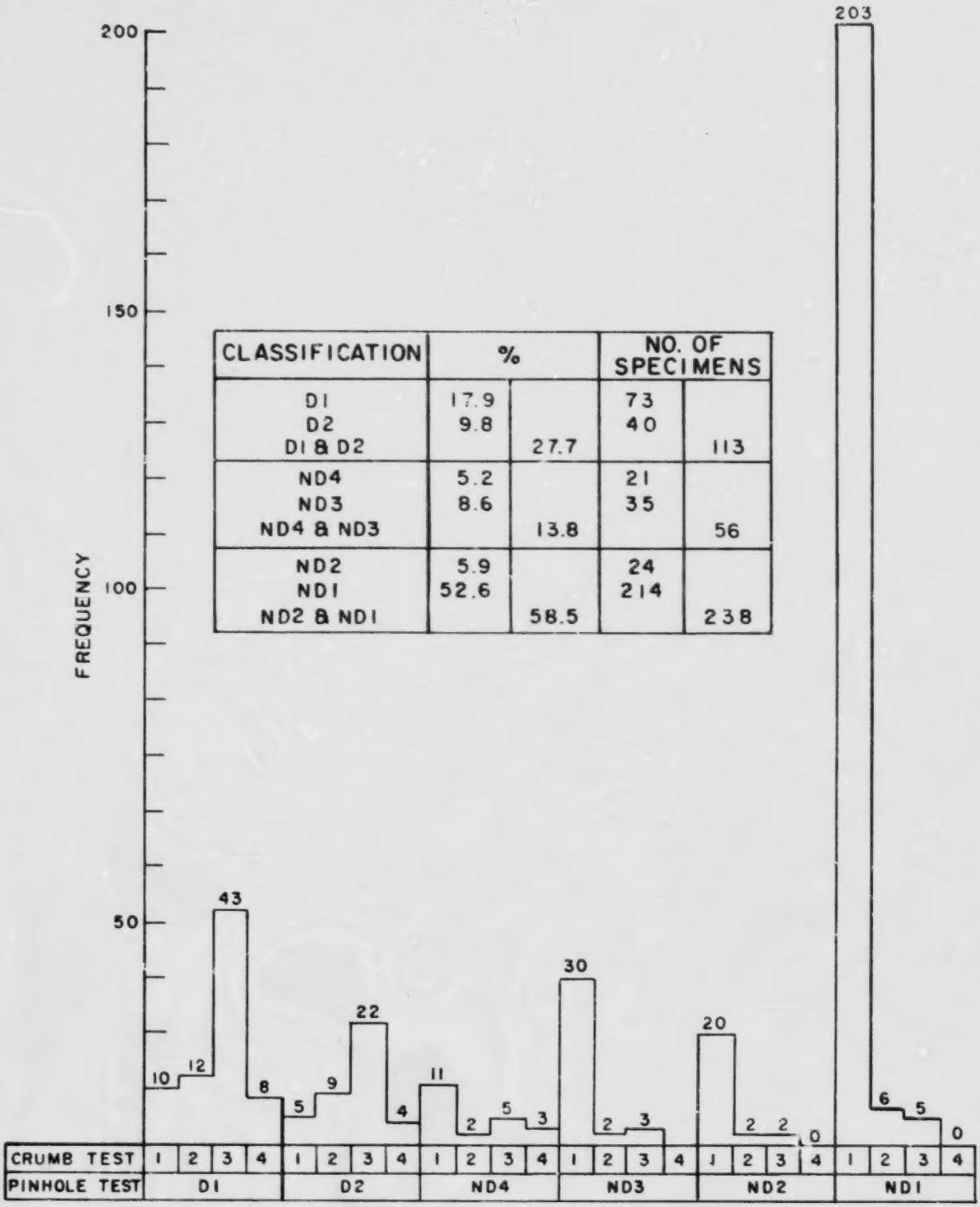

CLASSIFICATION	%		NO. OF SPECIMENS	
D1	17.9		73	
D2	9.8		40	
D1 & D2		27.7		113
ND4	5.2		21	
ND3	8.6		35	
ND4 & ND3		13.8		56
ND2	5.9		24	
ND1	52.6		214	
ND2 & ND1		58.5		238

Figure 4. – Dispersive grade versus frequency of occurrence.

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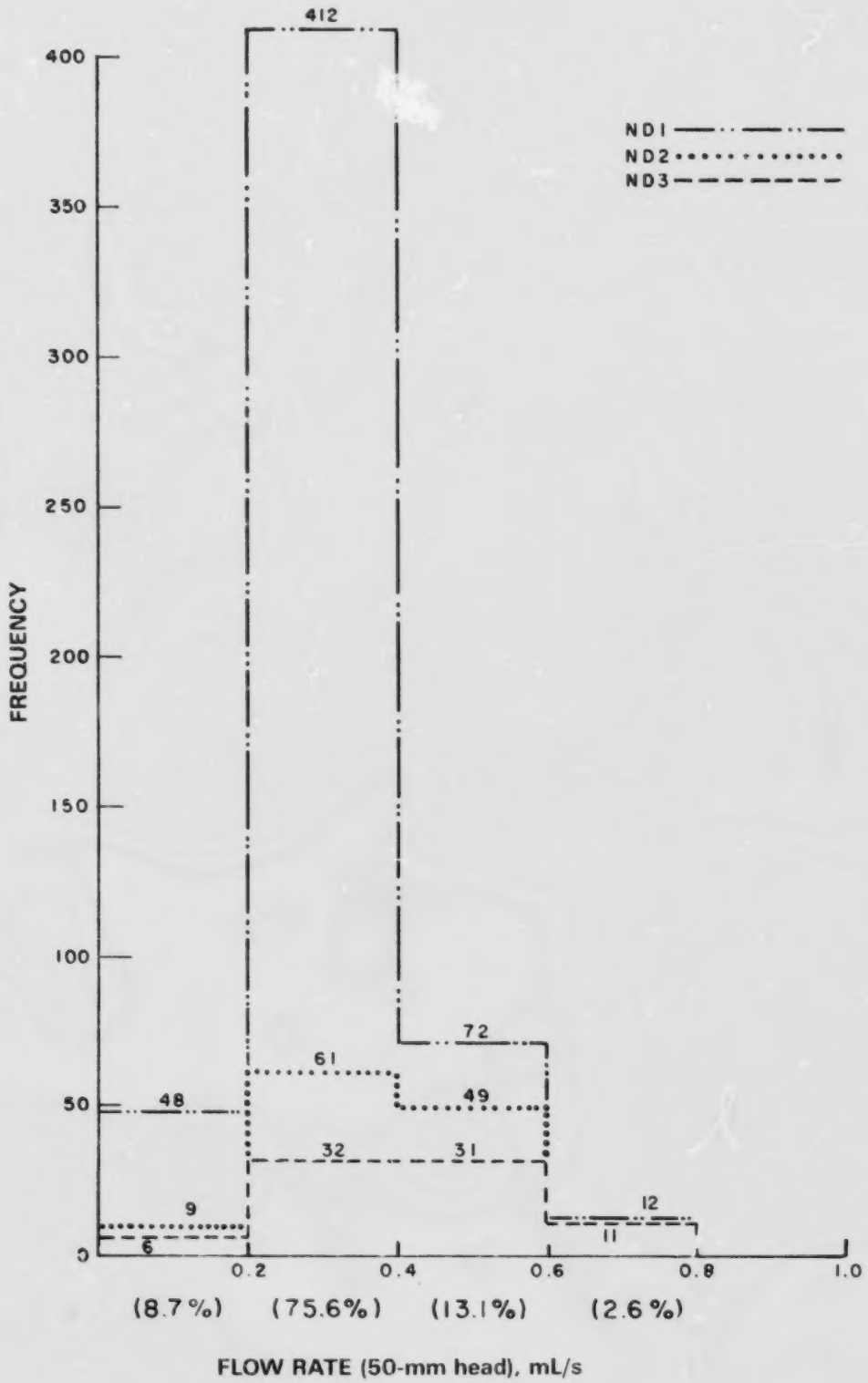

Figure 5. – Flow-rate data versus frequency of occurrence (sheet 1 of 3).

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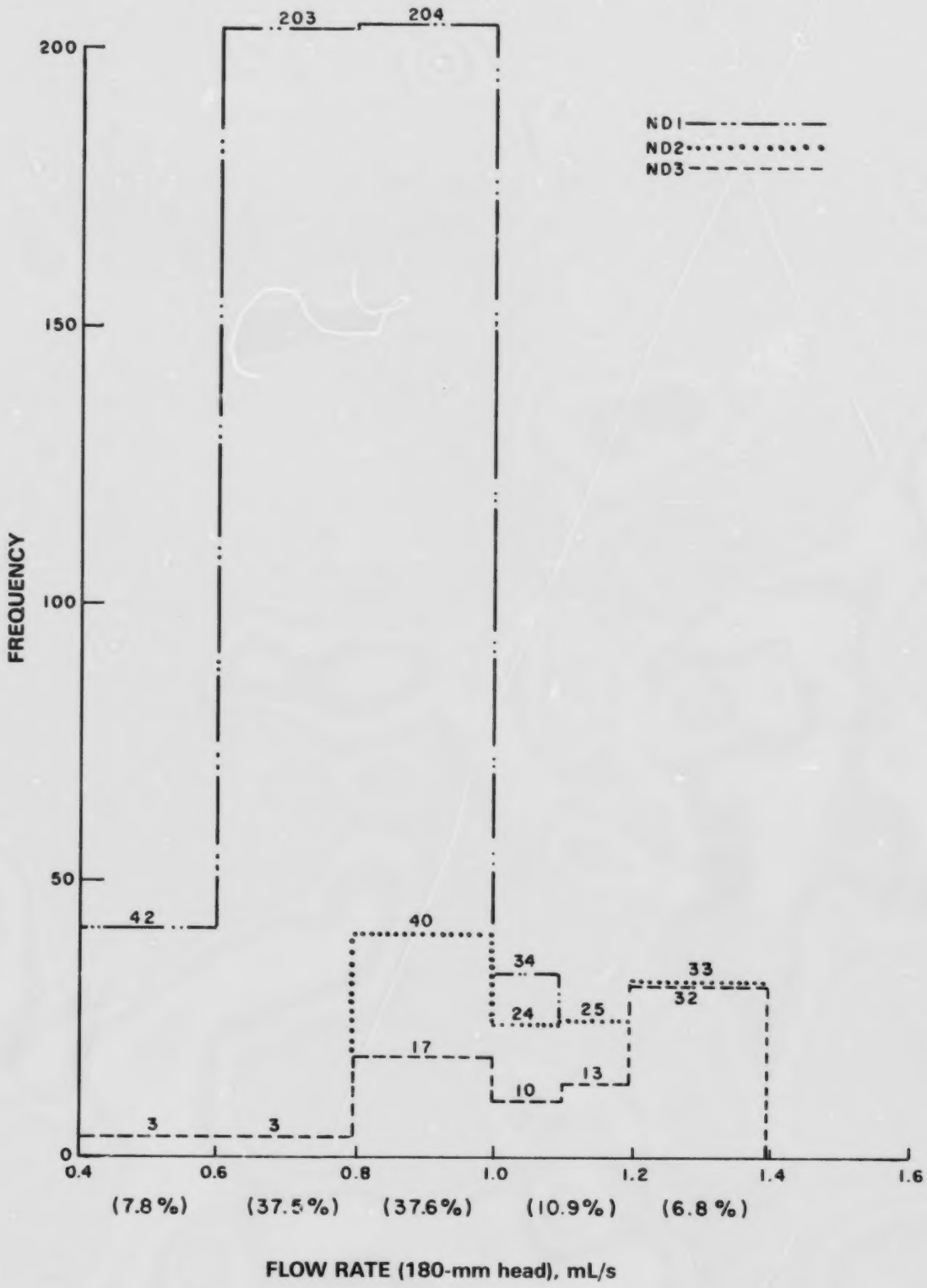

Figure 5. – Flow-rate data versus frequency of occurrence (sheet 2 of 3).

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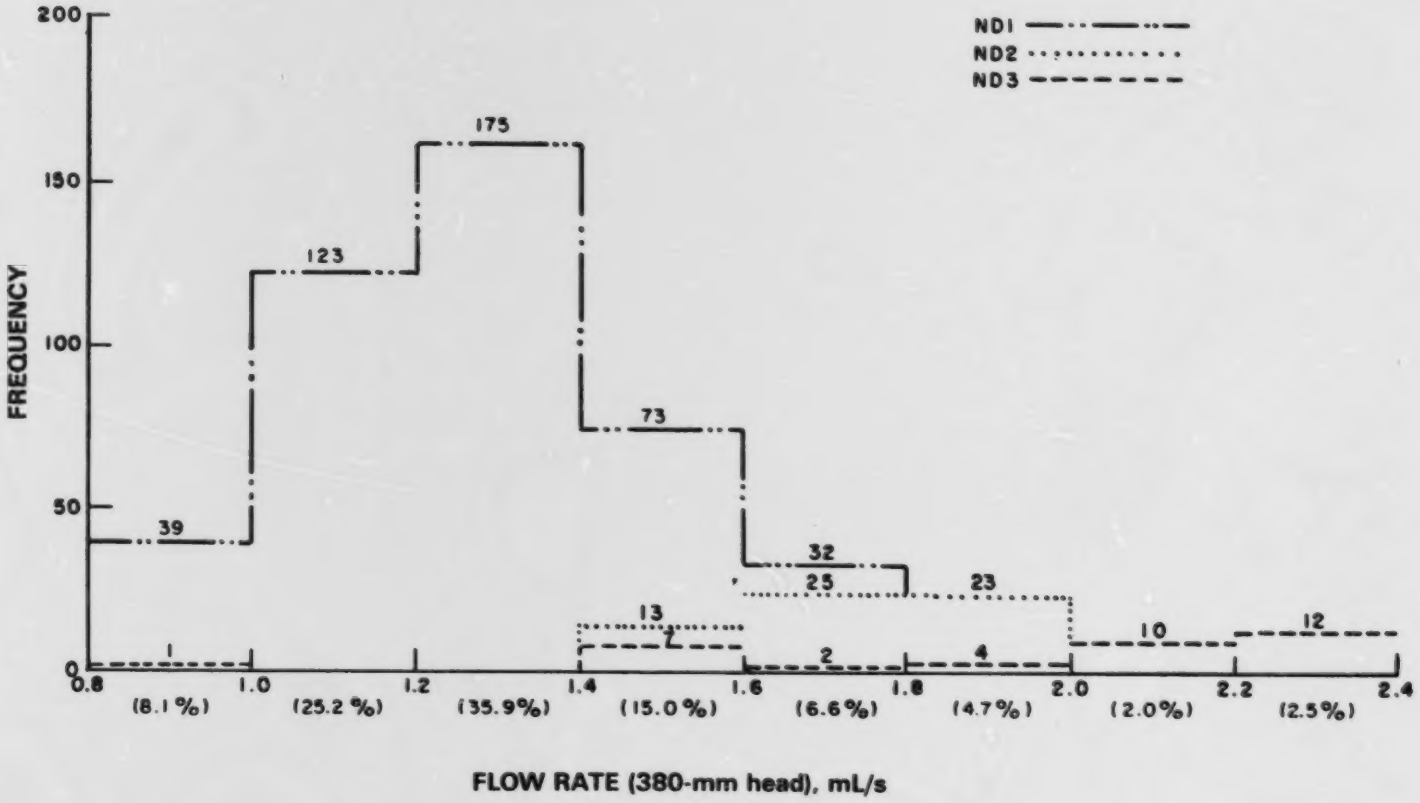

Figure 5. – Flow-rate data versus frequency of occurrence (sheet 3 of 3).

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in the literature [4, 6, 7, 12], for nondispersive soils, the original pinhole diameter remains unchanged and the flow rate remains constant at each head. For essentially all pinhole tests summarized in appendix M, the flow rates at each head remained constant for the entire duration of flow. The data entries represent the initial and final flow rates measured at each head. Appendix M is organized so that the frequency of occurrence of selected flow-rate ranges could be easily determined. The data of appendix M are also shown in the histogram on figure 5, which graphically shows the distribution of all flow-rate measurements and the variation that can exist in any set of flow-rate measurements.

Figure 15 of reference [7] was developed to relate Sherard's original pinhole test dispersive grades to flow rates obtained during the test. The major area of emphasis of the investigation for preparing reference [7] was the system flow rates for dispersive soils. For dispersive soils, the system flow rate is initially controlled by the 1.0-mm pinhole diameter, but is ultimately controlled by the hydraulic capacity of the 1.5-mm-diameter hole after the pinhole erodes. For nondispersive soils, the flow rate is always controlled by the pinhole, which remains 1.0-mm diameter throughout the test. Figure 15 of reference [7] was prepared from the pinhole test flow-rate data of approximately 300 dispersive-soil specimens and 60 nondispersive-soil specimens. When the flow-rate data of appendix M and figure 5 are compared with the flow-rate boundary zones on figure 15 of reference [7], it is apparent that minor adjustments of the ND3 and ND1 lower flow-rate boundaries are required.

Figure 1 shows the revised USBR pinhole test dispersive-grade versus flow-rate test evaluation criteria. This figure was developed directly from figure 15 of reference [7], with revisions reflecting the flow-rate data from the 273 nondispersive soil specimens in this report. Figure 1 shows dispersive-grade classification boundary zones, which now give a 95-percent confidence level for correctly classifying soils using pinhole test flow-rate data.

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APPENDIXES

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APPENDIX A
RED ROCKS PUMPING PLANT

Sample identification		Unified soil class.	Placement d (lb/ft³)	w (%)	Pinhole test data summary Head (mm)	Q_1 (mL/s)	Q_2 (mL/s)	Turbidity[a] Initial	Final	Classification	Crumb test	Remarks
AP-1-RRPP	0.0-5.0	SC	115.9	10.8	50	0.30	0.43	C	C	ND1	1	
					180	1.1	1.1	C	C			
					380	1.6	1.7	C	C			
AP-1-RRPP	13.0-49.0	CL	110.7	13.1	50	0.20	0.30	C	C	ND1	1	
					180	0.77	0.77	C	C			
					380	1.3	1.3	C	C			
AP-1-RRPP	56.0-63.0	CL	118.0	10.0	50	0.27	1.1	CL	CL	D2	3	
					180							
					380							
AP-1-RRPP	63.0-74.0	CL	109.3	13.9	50	0.30	0.35	C	C	ND1	1	
					180	0.90	0.92	C	C			
					380	1.6	1.6	C	C			
AP-1-RRPP	84.0-101.0	CL	104.0	16.2	50	0.83	1.1	CL	CL	D1	3	
					180							
					380							
AP-1-RRPP	101.0-106.0	SC-SM			50						1	
					180							
					380							
AP-1-RRPP	106.0-115.0	CL	109.9	12.9	50	0.42	0.78	CL	SC	ND3	2	
					180							
					380							
AP-1-RRPP	115.0-125.0	SC	118.1	9.9	50	0.37	0.33	SC	C	ND3	1	Hole plugged after 3 minutes flow at 180 mm head.
					180	1.23	0.72	SC	SC			
					380							
AP-2-RRPP	0.0-6.0	CL	112.2	12.8	50	0.25	0.47	C	C	ND3	1	
					180	1.2	1.1	SC	SC			
					380	2.0	2.0	CL	CL			
AP-2-RRPP	14.0-41.0	SC-CL	120.4	9.3	50	0.35	0.38	C	C	ND1	1	
					180	0.87	0.92	C	C			
					380	1.3	1.3	C	C			
AP-2-RRPP	41.0-54.0	CL	114.9	11.4	50	0.67	1.2	CL	CL	D1	1	
					180							
					380							
AP-2-RRPP	54.0-74.0	CL	114.9	12.5	50	1.2	1.2	CL	CL	D1	1	
					180							
					380							
AP-2-RRPP	83.0-95.0	CL	111.1	13.4	50	0.32	1.1	SC	SC	D1	1	
					180							
					380							
AP-2-RRPP	95.0-114.0	CL	112.6	12.2	50	0.57	1.1	CL	CL	D1	3	
					180							
					380							
AP-2-RRPP	114.0-117.0	SC	116.8	7.9	50	0.38	0.68	SC	C	ND3	1	
					180	1.6	1.7	C	C			
					380	2.6	2.6	C	C			
AP-2-RRPP	117.0-121.0	SC	122.8	7.9	50	0.23	0.23	C	C	ND1	1	
					180	0.65	0.63	C	C			
					380	1.1	1.1	C	C			
AP-2-RRPP	121.0-125.0	CL	114.7	11.2	50	0.65	0.7	C	C	ND3	1	
					180	1.6	1.5	C	C			
					380	2.6	3.0	C	C			
AP-3-RRPP	0.0-11.0	CL	116.0	14.3	50	0.27	0.27	C	C	ND1	1	
					180	0.75	0.87	C	C			
					380	1.5	1.5	C	C			
AP-3-RRPP	11.0-18.0	SC	125.1	7.1	50	0.30	0.28	C	C	ND1	1	
					180	0.75	0.75	C	C			
					380	1.3	1.2	C	C			
AP-3-RRPP	18.0-28.0	SC-CL	105.2	10.7	50	0.28	0.30	C	C	ND1	1	
					180	0.82	0.87	C	C			
					380	1.4	1.4	C	C			
AP-3-RRPP	28.0-35.0	CL	119.2	12.8	50	0.32	1.1	CL	CL	D2	2	
					180							
					380							
AP-4-RRPP	0.0-9.0	CL-SC	117.9	10.1	50	0.33	0.32	C	C	ND1	1	
					180	0.90	0.87	C	C			
					380	1.4	1.4	C	C			
AP-4-RRPP	14.0-19.0	SC	122.1	8.2	50	0.42	1.1	SC	SC	D1	1	
					180							
					380							
AP-4-RRPP	19.0-28.0	CL-SC	115.4	10.6	50	0.27	1.0	CL	CL	D2	2	
					180							
					380							
AP-4-RRPP	28.0-35.0	SC-CL	115.2	11.0	50	0.25	0.40	SC	C	ND1	1	
					180	0.88	0.90	SC	C			
					380	1.37	1.37	SC	C			

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APPENDIX B
BRADY PUMPING PLANT

Sample identification		Unified soil class.	Placement γ_d (lb/ft^3)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_1 (mL/s)	Q_4 (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
AP-1-BPP	0.0-6.0	SC-CL	125.5	9.8	50	0.27	0.28	C	C	ND1	1	
					180	0.63	0.63	C	C			
					380	1.0	1.0	C	C			
AP-1-BPPP	6.0-11.0	SC	118.2	12.1	50	0.23	0.25	C	C	ND1	1	
					180	0.60	0.58	C	C			
					380	0.95	0.93	C	C			
AP-1-BPP	11.0-32.0	SC	122.5	10.7	50	0.20	0.98	SC	SC	ND4	3	
					180	2.53	2.52	SC	SC			
					380							
AP-1-BPP	32.0-37.0	SC	114.0	13.4	50	0.38	0.58	SC	SC	ND4	4	
					180	2.2	2.4	SC	SC			
					380							
AP-1-BPP	37.0-58.0	SC	119.8	11.7	50	0.55	1.1	SC	SC	??	3	
					180							
					380							
AP-1-BPP	63.0-91.0	SC	120.2	11.7	50	0.48	1.0	SC	SC	D1	3	
					180							
					380							
AP-1-BPP	91.0-98.0	SC-CL	119.0	12.1	50	0.58	1.1	SC	SC	D2	3	
					180							
					380							
AP-1-BPP	98.0-125.0	CL	116.7	13.2	50	0.90	1.2	SC	SC	D1	4	
					180							
					380							
AP-2-BPP	7.0-36.0	SC	119.4	12.3	50	0.23	0.23	C	C	ND1	1	
					180	0.57	0.58	C	C			
					380	0.93	0.93	C	C			
AP-2-BPP	36.0-58.0	SC	108.9	11.3	50	0.17	1.2	CL	SC	D2	4	
					180							
					380							
AP-2-BPP	66.0-90.0	CL-SC	109.9	13.7	50	0.53	1.1	CL	CL	D1	3	
					180							
					380							
AP-2-BPP	90.0-106.0	CL-SC	121.0	12.6	50	0.32	0.45	SC	CL	ND3	3	
					180	1.07	1.03	CL	CL			
					380							
AP-2-BPP	106.0-119.0	SC	120.1	9.9	50	0.23	1.0	CL	CL	D2	3	
					180							
					380							
AP-2-BPP	119.0-125.0	CL	110.4	17.1	50	0.52	0.87	CL	SC	ND4	3	
			(107.5)	(15.2)	180	2.0	2.0	SC	SC			
					380							
AP-3-BPP	0.0-35.0	SC-SM	127.8	9.6	50	0.37	0.37	C	C	ND1	2	
			(122.6)	(8.1)	180	0.83	0.83	C	C			
					380	1.4	1.3	C	C			

[a] D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX C
TUCSON AQUEDUCT - REACH 2

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Qi (mL/s)	Qr (mL/s)	Turbidity* Initial	Final	Classification	Crumb test	Remarks
AP-101-TA2	6.0-8.5	SC	120.5	8.5	50	0.27	0.27	C	C	ND1	2	- No. 30 soil
					180	0.70	0.72	C	C			
					380	1.1	1.2	C	C			
AP-105-TA2	24.0-26.0	SC	117.6	9.6	50	0.33	0.32	C	C	ND1	1	- No. 30 soil
					180	0.85	0.83	C	C			
					380	1.4	1.4	C	C			
AP-108-TA2	10.0-21.0	SC	128.1	8.6	50	0.38	0.38	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.6	1.6	C	C			
AP-109-TA2	10.0-23.0	SC	128.1	9.4	50	0.42	0.42	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.5	1.5	C	C			
AP-111-TA2	16.0-18.0	GC-SC	117.1	15.9	50	0.72	0.2	C	C	ND1	1	- No. 30 soil
					180	0.62	0.65	SC	SC			
					380	1.1	1.2	SC	SC			
AP-112-TA2	0.0-4.0	CL-SC	117.9	10.9	50	0.27	0.27	SC	SC	ND1	2	
					180	0.67	0.72	C	C			
					380	1.2	1.1	C	C			
	17.0-20.0	SC	125.8	8.9	50	0.35	0.40	SC	C	ND1	2	- No. 30 soil
					180	0.90	0.95	C	C			
					380	1.4	1.5	C	C			
AP-113-TA2	0.0-23.0	CL	104.8	18.7	50	0.28	0.37	C	C	ND1	1	
					180	0.83	0.85	C	C			
					380	1.3	1.3	C	C			
AP-115-TA2	0.0-6.0	CL	111.4	15.3	50	0.22	0.22	C	C	ND1	2	
					180	0.62	0.60	C	C			
					380	1.0	1.0	C	C			
	6.0-13.0	CL	105.2	16.2	50	0.28	0.27	C	C	ND1	1	
					180	0.72	0.72	C	C			
					360	1.2	1.2	C	C			
	13.0-28.0	CL-SC	107.6	11.9	50	0.27	0.27	C	C	ND1	1	
					180	0.68	0.67	C	C			
					380	1.0	1.0	C	C			
AP-116-TA2	0.0-10.0	CL	108.9	11.5	50	0.30	0.30	C	C	ND1	1	
					180	0.80	0.80	C	C			
					380	1.3	1.3	C	C			
	18.0-23.0	CL-SC	116.7	12.5	50	0.27	0.27	C	C	ND1	1	
					180	0.68	0.67	C	C			
					380	1.1	1.1	C	C			
AP-118-TA2	0.0-7.0	CL	112.5	12.8	50	0.33	0.35	C	C	ND2	1	
					180	0.98	1.1	C	C			
					380	1.7	1.8	C	C			
	16.0-23.0	SC	119.3	9.3	50	0.25	0.25	C	C	ND1	1	
					180	0.63	0.63	C	C			
					380	1.1	1.1	C	C			
AP-120-TA2	8.0-30.0	CL	110.2	13.4	50	0.22	1.1	CL	CL	D2	2	
					180							
					360							
	8.0-30.0	CL	110.2	13.4	50	0.22	0.97	CC	CL	D2		Replicate test (see above)
					180							
					380							
AP-122-TA2	0.0-7.0	CL	107.2	13.5	50	0.27	0.27	C	C	ND1	1	
					180	0.68	0.67	C	C			
					380	1.1	1.1	C	C			
	7.0-13.0	CL	116.9	10.7	50	0.25	0.33	C	C	ND1	1	
					180	0.80	0.80	C	C			
					380	1.3	1.3	C	C			
	13.0-35.0	CL	102.1	15.1	50	0.23	0.52	CL	SC	ND4	1	
					180	2.0	2.6	CL	CL			
					380							
	13.0-35.0	CL	102.1	15.1	50	0.32	0.73	SC	CL	ND4		- No. 30 soil used for retest (see above)
					180	1.9	2.5	CL	CL			
					380							
AP-123-TA2	0.0-5.0	CL	106.0	15.2	50	0.22	0.33	C	C	ND1	1	Repunched hole at 2 min. flow at 50 mm head
					180	0.83	0.83	C	C			
					380	1.4	1.4	C	SC			
	5.0-11.0	SC-CL	110.5	12.8	50	0.33	0.32	C	C	ND1	1	
					180	0.78	0.79	C	C			
					380	1.3	1.3	C	C			
	11.0-30.0	CL	105.5	15.0	50	0.13	0.38	C	C	ND1	1	
					180	0.98	0.98	C	C			
					380	1.6	1.6	C	C			
AP-124-TA2	0.0-5.0	CL	102.5	15.6	50	0.43	0.38	C	C	ND1	1	
					180	0.97	0.97	C	C			
					380	1.6	1.6	C	C			

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APPENDIX C - Continued
TUCSON AQUEDUCT - REACH 2

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity[a] Initial	Final	Classification	Crumb test	Remarks
	5.0-11.0	SC	116.4	10.9	50	0.27	0.27	C	C	ND1	1	
					180	0.67	0.67	C	C			
					380	1.2	1.2	C	C			
AP-124-TA2	11.0-13.0	SC	119.0	9.5	50	0.23	0.23	C	C	ND1	1	
					180	0.65	0.65	C	C			
					380	1.1	1.0	C	C			
	13.0-30.0	SC-CL	107.9	13.9	50	0.32	0.32	C	C	ND2	1	
					180	0.90	0.90	C	C			
					380	1.6	1.6	C	C			
AP-126-TA2	0.0-10.0	CL	106.0	14.9	50	0.32	0.33	C	C	ND2	1	
					180	1.2	1.3	C	C			
					380	2.2	2.2	C	C			
	6.0-10.0	SC	114.3	11.3	50	0.33	0.33	C	C	ND1	1	
					180	0.85	0.85	C	C			
					380	1.4	1.4	C	C			
	20.0-30.0	CL			50	0.37	0.43	SC	SC	ND4	1	
					180	2.1	2.1	CL	CL			
					380							
AP-127-TA2	0.0-6.0	CL	114.3	11.6	50	0.30	0.30	C	C	ND1	1	
					180	0.77	0.77	C	C			
					380	1.2	1.2	C	C			
	6.0-13.0	SC		9.3	50	0.30	0.30	C	C	ND1	1	
					180	0.77	0.77	C	C			
					380	1.3	1.3	C	C			
	13.0-18.0	CL-SC	109.7	13.5	50	0.47	1.1	CL	CL	D2	1	
					180							
					380							
	18.0-25.0	SC	115.1	10.6	50	0.40	0.40	C	C	ND1	1	
					180	1.0	1.0	C	C			
					380	1.6	1.6	C	C			
	25.0-30.0	CL	113.8	11.7	50	0.30	0.98	CL	CL	ND4	1	
					180			CL	CL			
					380							
AP-129-TA2	0.0-6.0	CL	107.2	14.8	50	0.25	0.92	SC	CL	ND4	1	
					180	2.6	2.3	CL	CL			
					380							
	6.0-9.0	SC	107.4	8.4	50	0.33	0.33	C	C	ND1	1	
					180	0.82	0.82	C	C			
					380	1.3	1.3	C	C			
	9.0-22.0	CL-SC	113.9	14.8	50	0.33	0.33	SC	C	ND1	1	
					180	0.80	0.83	SC	C			
					380	1.3	1.3	C	C			
AP-129-TA2	22.0-30.0	SC-CL	118.1	10.5	50	0.42	0.47	CL	CL	ND3	1	
					180	1.0	0.98	CL	CL			
					380	1.6	3.5	CL	CL			
AP-130-TA2	0.0-0.6	CL	112.1	14.3	50	0.13	0.33	SC	CL	ND3	1	
					180	0.87	0.97	CL	CL			
					380	2.2	2.8	CL	CL			
	6.0-13.0	CL	112.0	12.1	50	0.33	0.28	C	C	ND1	1	
					180	0.78	0.78	C	C			
					380	1.3	1.3	C	C			
	13.0-17.0	CL	NA	NA	50	0.30	0.52	C	SC	ND3	1	
					180	1.3	1.3	SC	SC			
					380	2.5	2.7	SC	SC			
	27.0-35.0	CL	110.4	13.1	50	0.35	1.1	CL	CL	D1	3	
					180							
					380							
AP-131-TA2	0.0-6.0	CL	107.2	15.1	50	0.33	0.80	CL	C	ND4	1	
					180	1.8	2.1	C	C			
					380							
	6.0-8.0	CL-SC	114.9	11.5	50	0.25	0.35	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			
	8.0-10.5	SC	124.9	7.4	50	0.28	0.23	C	C	ND1	1	
					180	0.67	0.67	C	C			
					380	1.2	1.1	C	C			
	10.5-20.0	CL-SC	118.0	13.1	50	0.32	0.30	SC	C	ND1	1	
					180	0.77	0.80	C	C			
					380	1.3	1.4	C	C			
	20.0-26.0	SC	117.0	10.5	50	0.33	1.1	CL	CL	D2	1	- No. 30 soil
					180							
					380							
	26.0-35.0	CL	117.4	12.7	50	0.28	1.1	CL	CL	D2	2	
					180							
					380							

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APPENDIX C - Continued
TUCSON AQUEDUCT - REACH 2

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_1 (mL/s)	Q_4 (mL/s)	Turbidity* Initial	Final	Classification	Crumb test	Remarks
AP-133-TA2	16.0-25.0		117.0	12.5	50 180 380	0.35	1.1	CL	CL	D2	1	
	30.0-45.0		120.1	11.0	50 180 380	0.55	1.1	CL	CL	D2	2	
AP-137-TA2	0.0-5.0	CL	124.2	10.0	50 180 380	0.37 1.2 1.9	0.55 1.2 2.0	C C C	C C C	ND2	1	
	5.0-9.0	CL	117.4	12.8	50 180 380	0.63 1.0 1.6	0.42 1.0 1.6	CL SC SC	SC SC SC	ND3	1	
	9.0-19.0	SC	118.7	7.7	50 180 380	0.33 1.25	0.40 1.23	CL CL	CL CL	ND3	1	- No. 30 soil
	19.0-25.0	CL	119.5	11.7	50 180 380	0.38	1.1	CL	CL	D1	2	
	28.0-35.0	CL	116.0	12.2	50 180 380	0.20 0.83 1.33	0.32 0.82 1.33	C C C	C C C	ND1	1	
AP-139-TA2	18.0-35.0	CL	123.5	7.9	50 180 380	0.32 0.80 1.3	0.30 0.78 1.3	C C C	C C C	ND1	1	

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX D
TUCSON AQUEDUCT - REACH 3

Sample identification		Unified soil class.	Placement d (lb/ft³)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_1 (mL/s)	Q_6 (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
AP-101-TA3	13.0-20.0		121.2	11.3	50	0.30	0.33	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			
AP-103-TA3	10.0-14.0		119.8	9.0	50	0.25	0.30	C	C	ND1	1	Holes repunched to start flow at 50 mm head
					180	0.82	0.82	C	C			
					380	1.4	1.4	C	C			
	14.0-17.0		124.5	7.7	50	0.28	0.28	C	C	ND1	1	
					180	0.80	0.80	C	C			
					380	1.4	1.4	C	C			
	17.0-25.0		121.4	10.5	50	0.27	0.30	SC	C	ND3	1	
					180	0.80	0.92	SC	SC			
					380	1.5	1.6	SC	SC			
AP-105-TA3	9.0-25.0		121.5	10.9	50	0.28	0.28	C	C	ND1	1	
					180	0.73	0.73	C	C			
					380	1.2	1.2	C	C			
AP-107-TA3	7.0-13.0		117.9	11.1	50	0.28	0.28	C	C	ND1	1	
					180	0.82	0.82	C	C			
					380	1.4	1.4	C	C			
	13.0-25.0		122.8	10.6	50	0.33	0.35	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			
AP-109-TA3	8.0-21.0		120.0	10.7	50	0.37	0.35	C	C	ND1	1	
					180	0.92	0.92	C	C			
					380	1.4	1.4	C	C			
	21.0-25.0		116.4	12.0	50	0.43	1.0	CL	CL	D1	2	
					180							
					380							
	25.0-30.0		125.8	9.4	50	0.42	0.58	CL	CL	ND3	3	
					180	0.93	1.2	CL	CL			
					380							
AP-110-TA3	0.0-6.0		117.3	8.2	50	0.33	0.32	C	C	ND1	1	
					180	0.77	0.75	C	C			
					380	1.2	1.2	C	C			
	6.0-19.0		123.5	9.9	50	0.30	0.33	SC	C	ND1	1	
					180	0.87	0.85	SC	C			
					380	1.3	1.3	C	C			
	19.0-25.0		121.2	10.7	50	0.40	1.1	CL	CL	D1	2	
					180							
					380							
AP-111-TA3	10.0-18.0		114.7	13.0	50	0.23	0.35	C	C	ND2	1	
					180	0.95	0.95	C	C			
					380	1.6	1.7	C	C			
	18.0-25.0		125.2	17.8	50	0.33	0.97	SC	SC	ND4	2	
					180	2.2	2.5	SC	SC			
					380							
	25.0-30.0		115.4	12.7	50	0.25	0.35	C	C	ND2	1	
					180	0.90	0.88	C	C			
					380	1.6	1.6	SC	C			
AP-113-TA3	6.0-18.0		116.3	10.3	50	0.25	0.37	C	C	ND1	1	
					180	0.93	0.93	C	C			
					380	1.5	1.5	C	C			
	18.0-25.0		117.7	10.8	50	0.6	1.1	CL	CL	D2	3	
					180							
					380							
AP-114-TA3	10.0-18.0		121.0	13.4	50	0.25	0.30	C	C	ND1	1	
				8.9	180	0.73	0.73	C	C			
					380	1.2	1.2	C	C			
	18.0-23.0		123.4	10.3	50	0.25	0.57	C	C	ND3	1	
					180	1.4	1.4	SC	C			
					380							
AP-116-TA3	9.0-19.0		126.7	8.1	50	0.32	0.32	C	C	ND1	1	
					180	0.80	0.77	C	C			
					380	1.4	1.3	C	C			
AP-118-TA3	12.0-19.0		124.3	7.7	50	0.25	0.35	C	C	ND1	1	
					180	0.90	0.88	C	C			
					380	1.4	1.4	C	C			
	12.0-19.0		123.0	7.7	50	0.20	0.30	C	C	ND1		Replicate test - apparent shrinkage potential/expansion soil
					180	0.45	0.45	C	C			
					380	0.77	0.72	C	C			
AP-136-TA3	0.0-19.0		115.9	12.1	50	0.83	1.1	CL	CL	D1	1	
					180							
					380							
	19.0-25.0		111.6	15.1	50	0.37	0.38	C	C	ND2	1	
					180		1.0	C	C			
					380		1.7	C	C			

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APPENDIX D
TUCSON AQUEDUCT - REACH 3

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Final	Classification	Crumb test	Remarks
AP-137-TA3	0.0-12.0		101.5	21.0	50	0.20	0.58	SC	SC	ND3	1	
					180	1.4	1.5	SC	C			
					380							
AP-137-TA3	12.0-16.0		109.0	26.2	50	0.75	1.2	CL	CL	D1	1	
				16.2	180							
					380							
AP-138-TA3	6.0-18.0		116.9	10.7	50	0.27	0.32	C	C	ND1	1	
					180	0.80	0.80	C	C			
					380	1.3	1.3	C	C			
	18.0-30.0		110.5	14.6	50	0.73	1.2	CL	CL	D1	3	
					180							
					380							
AP-139-TA3	10.0-20.0		118.0	9.6	50	0.28	0.28	C	C	ND1	1	
					180	0.78	0.78	C	C			
					380	1.3	1.3	C	C			
AP-141-TA3	28.0-30.0		113.4		50	0.37	1.1	SC	SC	D1	3	
					180							
					380							

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX E
CLIFF DAM - DOWNSTREAM AREA

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Final	Classification	Crumb test	Remarks
TP-110-CSD	1.0-6.0	GC	111.4	11.4	50 180 380	0.25 1.2 1.6	0.53 0.22 0.4	SC C SC	C C SC	ND3	1	Hole repunched at 180 mm ND after clogging occurred
TP-118-CSD	1.0-4.0	CL	105.9	18.8	50 180 380	0.40 1.1	0.28 1.2	SC SC	C SC	ND3	1	
	1.0-4.0	CL	105.3	18.8	50 180 380	0.47 1.1	0.52 0.27	SC SC	SC CL	ND3		Replicate test
TP-123-CSD	1.5-4.0	CH	107.4	17.9	50 180 380	0.42 1.0	0.37 1.1	C SC	C C	ND3	1	Hole repunched three times to initiate flow at 50 mm head
TP-210-CSD	0.0-3.0	CL	120.2	10.6	50 180 380	0.30	1.0	CL	SC	D2	3	
TP-218-CSD	0.0-3.0	CH-SC	106.5	17.6	50 180 380	0.22	0.32	C	C	ND1	1	Hole repunched three times during first 5 minutes of flow at 50 mm head
TP-302-CSD	0.0-1.5	CL	120.1	11.5	50 180 380	0.83 1.2 2.1	0.87 1.5 2.2	C C C	C C C	ND3	1	* * * could be ND2 based on clear flow at 380 ND and 1 mm final pinhole
TP-308-CSD	0.0-5.0	CL-SC	108.3	15.1	50 180 380	0.48	1.1	CL	CL	D2	2	
TP-408-CSD	0.0-4.0	CL	117.3	13.6	50 180 380	0.82	1.1	CL	CL	D1	3	
TP-413-CSD	6.5-10.0	SC	108.0	16.2	50 180 380	0.32 0.87 1.4	0.37 0.88 1.5	C C C	C C C	ND1	1	
TP-519-CSD	11.5-18.0	CL-SC	114.0	11.8	50 180 380	0.60	1.1	CL	CL	D1	1	
TP-607-CSD	4.0-17.0	CL	99.8	22.5	50 180 380	0.35 1.2	0.47 1.2	C SC	SC C	ND3	1	
TP-608-CSD	1.5-8.0	CL-SC	105.9	15.8	50 180 380	0.23 0.95	0.38 1.1	SC CL	SC CL	ND3	1	- No. 30 soil - soil erosion sketch shows trumpeting disoriginal pinhole V/S
AH-617-CSD	0.0-4.5	CL	114.1	15.1	50 180 380	0.20 1.0	0.37 1.0	C C	C C	ND3	1	* * * could be ND1 based on 1 mm final diameter hole clear flow
AH-619-CSD	3.0-5.0	CL	107.4	16.2	50 180 380	0.18 0.95 1.5	0.32 0.95 1.6	C C C	C C C	ND1	1	

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX F
TUCSON AQUEDUCT - REACH 1

Sample identification	Unified soil class.[a]	Placement γ_d (lb/ft^3)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
AP-137-TA1 Sta 349+20 5.0-10.0	CL	114.2	11.5	50	0.28	0.90	CL	SC	ND4	1	
				180	2.2	2.8	CL	C			
				380							
10.0-15.0	SC-SM	119.7	11.2	50	0.47	1.1	CL	SC	D1	3	
				180							
				380							
15.0-20.0	SC			50	0.58	1.2	CL	CL	D1	4	- No. 30 soil
				180							
				380							
20.0-25.0	SC	118.0	10.8	50	0.23	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
25.0-30.0	CL	113.6	11.3	50	0.30	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
30.0-35.0	SC	115.4	10.0	50	0.43	1.1	CL	CL	D1	3	- No. 30 soil
				180							
				380							
AP-138-TA1 Sta 359+70 0.0-5.0	SC-CL	119.1	9.5	50	0.43	1.1	CL	CL	D1	3	- No. 30 soil
				180							
				380							
5.0-10.0	SC-SC	115.9	10.6	50	0.32	1.1	SC	SC	D1	2	- No. 30 soil
				180							
				380							
10.0-15.0	SC	122.2	8.7	50	0.37	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
15.0-20.0	SC	120.8	10.1	50	0.20	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
20.0-25.0	SC	118.5	10.0	50	0.38	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
25.0-30.0	SC	119.6	10.0	50	0.35	1.1	SC	SC	D1	3	
				180							
				380							
30.0-35.0	SC	114.0	11.3	50	0.30	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
AP-138-TA1 Sta 359+70 35.0-40.0	SC	121.2	9.1	50	0.40	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
AP-139-TA1 Sta 366+50 0.0-5.0	SC	124.9	8.6	50	0.43	1.1	CL	CL	D1	3	- No. 30 soil
				180							
				380							
0.5-10.0	SC-CL	120.7	10.7	50	0.30	0.30	C	C	ND1	1	
				180	0.77	0.77	C	C			
				380	1.3	1.3	C	C			
10.0-15.0	SC	124.8	8.7	50	0.28	0.28	C	C	ND1	1	- No. 30 soil
				180	0.75	0.75	C	C			
				380	1.2	1.2	C	C			
15.0-20.0	SC	118.8	10.9	50	0.32	1.1	SC	SC	D2	3	- No. 30 soil
				180							
				380							
20.0-25.0	SC	116.7	10.0	50	0.30	1.1	SC	SC	D2	3	- No. 30 soil
				180							
				380							
25.0-30.0	SC	115.2	11.8	50	0.30	0.30	SC	SC	ND1	1	- No. 30 soil
				180	0.72	0.72	SC	SC			
				380	1.1	1.1	SC	SC			
30.0-35.0	SC	118.0	11.0	50	0.32	1.1	SC	SC	D1	3	- No. 30 soil
				180							
				380							
35.0-40.0	SC	119.3	11.5	50	0.30	1.1	CL	SC	D1	4	- No. 30 soil
				180							
				380							
40.0-45.0	SC	118.8	11.3	50	0.30	1.1	CL	SC	D1	3	- No. 30 soil
				180							
				380							
45.0-50.0	SC	113.3	13.1	50	0.42	1.1	CL	CL	D1	3	- No. 30 soil
				180							
				380							
AP-140-TA1 Sta 367+30, 40 LT 5.0-10.0	SC	119.6	9.4	50	0.30	1.1	SC	SC	D2	3	- No. 30 soil
				180							
				380							

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APPENDIX F - Continued
TUCSON AQUEDUCT - REACH 1

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Final	Classification	Crumb test	Remarks
	10-15.0	SC	123.0	10.0	50 180 380	0.30	1.1	SC	SC	D2	3	- No. 30 soil
AP-140-TA1 Sta 375+30, 40 LT	15.0-25.0	SC	120.3	9.3	50 180 380	0.30	1.1	SC	SC	D2	3	- No. 30 soil
	20.0-25.0	SC	118.6	11.1	50 180 380	0.35	1.1	SC	SC	D1	3	- No. 30 soil
	25.0-30.0	SC	117.5	10.8	50 180 380	0.30	1.1	SC	SC	D1	3	- No. 30 soil
	30.0-35.0	SC	121.0	9.9	50 180 380	0.40	1.1	SC	SC	D1	3	- No. 30 soil
	35.0-40.0	SC	119.7	10.1	50 180 380	0.37	1.1	SC	SC	D1	3	- No. 30 soil
AP-141-TA1 Sta 375+30 50 RT	0.0-5.0	SC	126.1	8.4	50 180 380	0.48	1.1	CL	CL	D1	2	- No. 30 soil
	5.0-10.0	SC-CL	117.4	11.6	50 180 380	0.30 0.82 1.3	0.30 0.82 1.3	C C C	C C C	ND1	1	- No. 30 soil
	10.0-15.0	SC	116.7	9.9	50 180 380	0.30	1.1	SC	SC	D2	3	- No. 30 soil
	15.0-20.0	SC	119.5	10.9	50 180 380	0.35	1.1	SC	SC	D1	3	- No. 30 soil
	20.0-25.0	SC	116.7	11.2	50 180 380	0.30	1.1	C	SC	D2	3	- No. 30 soil
	25.0-30.0	SC	114.7	12.5	50 180 380	0.43	1.1	SC	SC	D1	2	- No. 30 soil
	30.0-35.0	SC	119.3	9.8	50 180 380	0.45	1.1	SC	SC	D1	3	- No. 30 soil
	35.0-40.0	SC	118.0	11.0	50 180 380	0.32	1.1	SC	SC	D2	3	- No. 30 soil
AP-142-TA1 Sta 382+15	0.0-5.0	SC-SM	122.8	8.1	50 180 380	0.53	1.1	SC	SC	D1	3	- No. 30 soil
	5.0-10.0	SC	119.1	9.8	50 180 380	0.30 0.82 1.4	0.30 0.82 1.4	C C C	C C C	ND1	1	- No. 30 soil
	10.0-15.0	SC	122.6	9.2	50 180 380	0.30 0.83 1.4	0.30 0.83 1.4	C C C	C C C	ND1	1	- No. 30 soil
	15.0-20.0	SC	118.8	10.5	50 180 380	0.30 0.93 2.3	0.35 1.0 3.8	SC C SC	C SC SC	ND3	1	- No. 30 soil
	20.0-25.0	SC	117.1	11.1	50 180 380	0.37	1.1	SC	SC	D1	2	- No. 30 soil
	25.0-30.0	SC	111.2	13.9	50 180 380	0.30 1.8	0.57 2.6	SC SC	SC SC	ND4	1	- No. 30 soil
	30.0-35.0	SC	119.3	8.9	50 180 380	0.35	1.1	SC	SC	D1	4	- No. 30 soil
	35.0-40.0	SC	114.7	11.9	50 180 380	0.55	1.1	SC	SC	D1	3	- No. 30 soil

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX G
TUCSON AQUEDUCT - REACH 1 - BORROW AREA

Sample identification		Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity[a] Initial	Final	Classification	Crumb test	Remarks
AP-134-TA1	5.0-17.0	SC	125.3	9.1	50	0.33	0.65	C	SC	ND3	2	Apparent plugging at 180 mm head
					180	1.5	0.80	SC	SC			
					380							
	17.0-33.0	SC	117.4	9.6	50	0.40	0.62	SC	C	ND3	1	
					180	1.4	1.3	C	C			
					380	2.1	1.7	C	C			
	33.0-50.0	SC	117.8	11.1	50	0.32	0.88	SC	SC	ND4	1	
					180	2.4	2.5	SC	SC			
					380							
	58.0-65.0	SC	113.4	11.6	0	0.38	0.40	SC	C	ND1	1	
					180	0.93	0.90	C	C			
					380	1.4	1.4	C	C			
AP-135-TA1	0.0-8.0	SC-CL	126.4	9.2	50	0.30	1.1	SC	SC	D2	2	
					180							
					380							
	8.0-18.0	SC-CL	122.6	10.4	50	0.35	0.33	C	C	ND3	1	
					180	0.88	1.2	C	SC			
					380	2.7						
	18.0-22.0	SC-SM	119.2	9.9	50	0.52	1.1	SC	SC	D2	2	
					180							
					380							
	22.0-30.0	SC-CL	116.3	10.5	50	0.27	1.1	SC	C	D2	4	
					180							
					380							
	30.0-36.0	SC-SM	121.4	10.5	50	0.38	1.1	SC	SC	D2	3	
					180	1.8	2.3	CL	CL			
					380							
	36.0-40.0	SC	120.9	9.6	50	0.55	1.1	CL	CL	D1	3	
					180							
					380							
	0.0-9.0	SC-CL	123.7	8.9	50	0.42	1.1	CL	SC	D1	3	
					180							
					380							
	13.0-19.0	SC-CL	117.6	11.4	50	0.35	1.1	SC	SC	D2	3	
					180							
					380							
	19.0-34.0	SC-CL	115.9	10.5	50	0.32	0.65	SC	SC	ND4	3	
					180	1.0	2.5	SC	SC			
					380							
AP-201-TA1	21.0-28.0	CL	117.9	11.1	50	0.28	0.33	C	C	ND1	1	
					180	0.90	0.87	C	C			
					380	1.5	1.5	C	C			
AP-202-TA1	10.0-24.0	CL-SC	115.5	11.1	50	0.35	0.35	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			
	24.0-35.0	CL-SC	125.8	9.1	50	0.22	0.35	C	C	ND1	1	
					180	0.90	0.90	C	C			
					380	1.5	1.5	C	C			
AP-203-TA1	6.0-40.0	SC-CL	119.5	11.7	50	0.27	0.27	C	C	ND1	1	
					180	0.63	0.63	C	C			
					380	1.2	1.3	C	C			
AP-204-TA1	8.0-15.0	SC	126.5	7.6	50	0.20	0.48	C	C	ND2	1	- No. 30 soil
					180	1.2	1.2	C	C			
					380	1.9	1.9	C	C			
AP-205-TA1	11.0-40.0	SC	120.4	8.7	50	0.25	0.37	C	C	ND1	1	Holes repunched to start flow at 50 mm head
					180	0.90	0.90	C	C			
					380	1.4	1.4	C	C			
AP-207-TA1	0.0-9.0	SC	120.4	9.0	50	0.25	0.43	C	C	ND2	1	* * * could be ND1 based on clear flow and final 1.0 mm pinhole diameter
					180	1.0	1.0	C	C			
					380							
	9.0-18.0	SC	112.7	12.1	50	0.63	1.1	CL	SC	D1	3	- No. 30 soil
					180							
					380							
	18.0-26.0	SC	121.0	9.9	50	0.35	1.1	SC	SC	D2	3	
					180							
					380							
	26.0-40.0	SC	122.0	9.9	50	0.17	1.1	SC	[illegible]	D2	3	
					180							
					380							
AP-208-TA1	11.0-19.0	SC	114.8	11.1	50	0.32	0.33	C	C	ND1	1	
					180	0.82	0.82	C	C			
					380	1.4	1.4	C	C			
	19.0-40.0	SC	115.7	10.4	50	0.28	0.50	SC	C	ND3	1	Hole repunched at 2 min at 50 mm head
					180	1.3	1.3	SC	C			
					380							

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APPENDIX G - Continued
TUCSON AQUEDUCT - REACH 1 - BORROW AREA

Sample identification		Unified soil class.	Placement d (lb/ft³)	w (%)	Pinhole test data summary: Head (mm)	Q_i (mL/s)[a]	Q_f (mL/s)	Turbidity[a] Initial	Final	Classification	Crumb test	Remarks
AP-209-TA1	12.0-19.0	SC-SM	125.7	9.2	50	0.27	0.27	C	C	ND1	1	
					180	0.75	0.75	C	C			
					380	1.2	1.2	C	C			
	19.0-31.0	SC	118.7	9.9	50	0.55	0.55	C	C	ND3	1	Could be ND1 based on final pinhole size and clear flow at 180 mm head
					180	1.2	1.2	C	C			
					380							
	31.0-40.0	SC	120.4	9.0	50	0.35	0.65	SC	SC	ND3	3	Hole repunched three times. Questionable flow rate data
					180	0.77	1.1	SC	SC			
					380							
AP-210-TA1	34.0-40.0	SC	122.5	10.0	50	0.22	0.35	C	C	ND1	1	
					180	0.82	0.82	C	C			
					380	1.3	1.3	C	C			
AP-212-TA1	0.0-9.0	SC	123.1	9.2	50	0.27	0.42	C	C	ND3	1	Should be ND1 based on final pinhole sizes and clear flow
					180	1.1	1.1	C	C			
					380	1.6	1.6	C	C			
	21.0-34.0	SC-CL	121.5	10.6	50	0.35	1.1	SC	SC	D2	1	
					180							
					380							
AP-213-TA1	9.0-26.0	SC-CL	118.5	10.5	50	0.30	0.37	SC	C	ND1	1	
					180	0.85	0.83	C	C			
					380	1.3	1.3	C	C			
	26.0-40.0	SC-CL	111.9	14.2	50	0.33	0.33	C	C	ND1	1	
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			
AP-214-TA1	9.0-23.0	SC-CL	121.1	8.6	50	0.22	0.32	C	C	ND1	1	
					180	0.83	0.83	C	C			
					380	1.4	1.4	C	C			
	32.0-40.0	SC	118.6	9.4	50	0.38	0.68	SC	C	ND3	1	
					180	1.6	1.6	C	C			
					380							
AP-215-TA1	23.0-31.0	SC	116.3	10.6	50	0.32	0.58	SC	SC	ND3	1	
					180	1.2	1.9	SC	SC			
					380							
	31.0-40.0	SC	118.5	10.0	50	0.30	1.1	SC	SC	D2	2	
					180							
					380							
AP-216-TA1	5.0-10.0	SC	122.4	9.8	50	0.30	0.30	C	C	ND1	1	
					180	0.76	0.78	C	C			
					380	1.3	1.3	C	C			
	15.0-20.0	SC	121.2	9.2	50	0.30	0.30	C	C	ND1	1	- No. 30 soil
					180	0.82	0.82	C	C			
					380	1.4	1.4	C	C			
AP-216-TA1	20.0-25.0	SC-CL	117.3	11.9	50	0.33	0.35	C	C	ND1	1	- No. 30 soil
					180	0.90	0.90	C	C			
					380	1.5	1.5	C	C			
	25.0-30.0	SC-CL	117.7	11.3	50	0.27	0.30	C	C	ND1	1	Repunched hole to start flow at 50 mm head - No. 30 soil
					180	0.78	0.78	C	C			
					380	1.3	1.3	C	C			
	30.0-35.0	SC	116.0	10.3	50	0.33	0.33	C	C	ND1	1	- No. 30 soil
					180	0.82	0.82	C	C			
					380	1.3	1.3	C	C			
	35.0-40.0	SC-CL	117.9	11.5	50	0.32	1.1	SC	SC	D1	3	- No. 30 soil
					180							
					380							
	40.0-45.0	SC	117.2	11.3	50	0.30	1.1	SC	SC	D2	2	- No. 30 soil
					180							
					380							
	45.0-50.0	SC	118.8	9.3	50	0.32	1.1	SC	SC	D1	2	- No. 30 soil
					180							
					380							
AP-217-TA1	5.0-10.0	SC	117.5	11.2	50	0.38	1.1	SC	SC	D1	3	- No. 30 soil
					180							
					380							
	10.0-15.0	SC	121.0	9.0	50	0.32	0.32	C	C	ND1	1	- No. 30 soil
					180	0.85	0.85	C	C			
					380	1.5	1.5	C	C			
	15.0-20.0	SC	121.6	9.4	50	0.35	0.35	C	C	ND1	1	- No. 30 soil
					180	0.83	0.83	C	C			
					380	1.4	1.4	C	C			
	20.0-25.0	SC	117.9	10.1	50	0.35	0.35	C	C	ND1	2	- No. 30 soil
					180	0.83	0.83	C	C			
					380	1.4	1.4	C	C			
	25.0-30.0	SC	117.6	11.0	50	0.35	0.35	C	C	ND1	1	- No. 30 soil
					180	0.88	0.88	C	C			
					380	1.4	1.4	C	C			

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APPENDIX G - Continued
TUCSON AQUEDUCT - REACH 1 - BORROW AREA

Sample identification		Unified soil class.	Placement d (lb/ft³)	Placement w (%)	Pinhole test data summary Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
	30.0-35.0	SC-CL	108.7	14.4	50	0.35	0.43	SC	C	ND1	1	- No. 30 soil
					180	0.93	0.93	C	C			
					380	1.6	1.6	C	C			
	35.0-40.0	SC	124.4	8.3	50	0.32	1.1	SC	SC	D1	3	- No. 30 soil
					180							
					380							
AP-217-TA1	40.0-45.0	SC-CL	114.7	11.9	50	0.38	0.95	CL	C	ND4	1	
					180	2.1	2.1	C	C			
					380							
	45.0-50.0	SC	117.6	11.4	50	0.38	0.52	SC	C	ND2	1	- No. 30 soil
					180	1.2	1.2	C	C			
					380	1.9	1.9	C	C			
AP-218-TA1	5.0-10.0	SC	119.1	9.8	50	0.25	0.30	C	C	ND1	1	- No. 30 soil
					180	0.80	0.80	C	C			
					380	1.3	1.3	C	C			
	10.0-15.0	SC	122.2	8.6	50	0.30	0.32	C	C	ND1	1	- No. 30 soil
					180	0.80	0.80	C	C			
					380	1.4	1.4	C	C			
	15.0-20.0	SC	118.8	10.5	50	0.42	1.1	SC	SC	D1	1	- No. 30 soil
					180							
					380							
	20.0-25.0	SC	119.3	10.5	50	0.28	1.0	SC	SC	D2	1	- No. 30 soil
					180							
					380							
	25.0-30.0	SC	123.9	8.3	50	0.42	1.1	CL	SC	D1	3	- No. 30 soil
					180							
					380							
	30.0-35.0	CL	111.6	11.9	50	0.42	1.1	CL	CL	D1	1	- No. 30 soil
					180							
					380							
	35.0-40.0	SC	124.6	8.7	50	0.37	1.1	CL	SC	D1	3	- No. 30 soil
					180							
					380							
	40.0-45.0	SC	122.2	9.2	50	0.42	1.2	CL	CL	D1	2	- No. 30 soil
					180							
					380							
	45.0-50.0	SC	112.1	10.4	50	0.30	0.70	CL	C	ND3	1	
					180	1.7	1.7	C	C			
					380							
AP-219-TA1	0.0-5.0	SC-SM	126.6	7.1	50	0.25	0.38	C	C	ND2	1	- No. 30 soil
					180	0.95	0.95	C	C			
					380	1.6	1.7	C	C			
	5.0-10.0	SC	120.8	9.2	50	0.28	0.32	C	C	ND1	1	- No. 30 soil
					180	0.80	0.80	C	C			
					380	1.3	1.3	C	C			
AP-219-TA1	10.0-15.0	SC	123.2	7.5	50	0.33	0.35	SC	C	ND1	2	- No. 30 soil
					180	0.92	0.92	C	C			
					380	1.4	1.4	C	C			
	15.0-20.0	SC	120.2	9.7	50	0.33	1.1	SC	CL	D1	2	- No. 30 soil
					180							
					380							
	20.0-25.0	SC	117.8	9.9	50	0.33	1.0	CL	SC	D1	2	- No. 30 soil
					180							
					380							
	25.0-30.0	SC-CL	115.9	11.7	50	0.43	1.2	CL	CL	D1	1	- No. 30 soil
					180							
					380							
	30.0-35.0	SC-CL	112.6	12.8	50	0.27	1.2	CL	SC	D1	2	- No. 30 soil
					180							
					380							
	35.0-40.0	SC	116.9	9.3	50	0.28	1.1	CL	SC	D1	3	- No. 30 soil
					180							
					380							
	40.0-45.0	SC	111.8	11.0	50	0.30	1.1	CL	SC	D1	1	- No 30 soil
					180							
					380							
	45.0-50.0	SC	116.4	9.6	50	0.25	1.1	CL	SC	D1	3	- No. 30 soil
					180							
					380							

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX H
MISC. SPECIMENS NO. 4 and 10 COMPARISON TESTS

Sample Identification		Unified soil class.	Placement d (lb/ft³)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_i (mL/s)	Q_y (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
LaVerkin Springs	61Z-1	MH	94.0	25.3	50 180 380	0.37	1.1	SC	SC	D1	1	- No. 4 soil
	61Z-1	MH	93.1	25.3	50 180 380	0.33	1.0	SC-CL	SC	D1	-	- No. 10 soil - replicate pinhole test
	61Z-2	MH-ML	98.5	22.3	50 180 380	0.37 2.1	0.25 1.2	SC SC	SC SC	ND4	1	- No. 4 soil
	61Z-2	MH-ML		22.3	50 180 380	0.18 1.1	0.43 2.4	SC SC	SC SC	ND4	-	- No. 10 soil - replicate pinhole test
	61Z-3	MH	94.9	27.0	50 180 380	0.38	0.68	SC	SC	ND4	2	Test stopped at 50 mm ND due to excessive plugging. - No. 4 soil
	61Z-3	MH	94.0	27.0	50 180 380	0.20	0.70	SC	SC	ND4	-	- No. 10 soil - test stopped at 50 mm head due to excessive plugging
San Justo Dam	59N-396	CL	106.9	17.8	50 180 380	0.10 0.60 2.2	0.11 1.0 2.7	C SC SC	C SC C-SC	ND3	-	- No. 10 soil
	59N-398	SC	105.5	18.9	50 180 380	0.23	1.1	SC	SC	D2	-	- No. 10 soil
	59N-404	CL	101.9	15.8	50 180 380	0.38 2.4	0.87 2.5	CL D	CL D	ND4	-	- No. 4 soil
	59N-404	CL	103.8	15.8	50 180 380	0.13	1.1	CL	D	D2	-	Replicate test using - No. 10 soil
	59N-404	CL	103.8	15.8	50 180 380	0.21	1.1	CL	D	D2	-	Replicate test using - No. 10 soil
	59N-405	CL	105.8	16.3	50 180 380	0.16 2.6	0.88 2.5	CL D	CL D	ND4	-	- No. 10 soil - Hole repunched to start flow at 50 mm head
	59N-405 (w/screen D/S)	CL	106.3	16.3	50 180 380	0.10	0.92	D	D	ND4	-	- No. 10 soil - Hole repunched to start flow at 50 mm head
	59N-406	CL	102.4	20.2	50 180 380	0.14	1.0	CL	D	D2	-	- No. 10 soil
	59N-410	CL	98.1	25.7	50 180 380	0.15 1.7	0.67 1.6	C C	C C	ND3	-	- No. 10 soil - Hole repunched to start flow at 50 mm head
	59N-414 (w/screen D/S)	SC	107.2	18.0	50 180 380	0.18 0.82 1.4	0.20 0.82 1.4	C C C	C C C	ND1	-	
	59N-414 (w/screen D/S)	SC	107.8	18.0	50 180 380	0.27 0.57 0.95	0.18 0.55 0.92	C C C	C C C	ND1	-	

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX I
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Placement d (kg/m³)	Placement w (%)	Pinhole test data summary Head (mm)	Qi (mL/s)	Qr (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
BAF: F-2 North End	CL-ML	1825	10.7	50	0.4	0.4	C	C	ND1	1	Natural soil
				180	0.8	0.9	C	C			
				380	1.4	1.4	C	C			
	CL-ML	1829	10.7	50	0.4	0.4	C	C	ND1	1	Natural soil replicate test
				180	0.8	0.9	C	C			
				380	1.4	1.5	C	C			
	SC	1996	17.4	50	0.2	0.2	C	C	ND1	1	Premix
				180	0.7	0.7	C	C			
				380	1.1	1.2	C	C			
	SC	1967	17.4	50	0.2	0.2	C	C	ND1	1	Premix replicate test
				180	0.8	0.8	C	C			
				380	1.3	1.3	C	C			
	SM	1765	15.9	50	0.5	0.5	C	C	ND1	1	Final mix
				180	0.9	0.9	C	C			
				380	1.5	1.5	C	C			
	SM	1787	15.9	50	0.5	0.5	C	C	ND1	1	Final mix replicate test
				180	1.0	1.1	C	C			
				380	1.6	1.6	C	C			
BAF: F-2 South end	CL-ML	1902	8.2	50	0.3	0.3	C	C	ND1	1	Natural soil
				180	0.9	0.9	C	C			
				380	1.5	1.5	C	C			
	CL-ML	1779	8.2	50	0.5	0.5	C	C	ND2	1	Natural soil replicate test
				180	1.1	1.2	C	C			
				380	1.8	1.9	C	C			
	ML	1830	17.1	50	0.5	0.5	C	C	ND3	1	Premix
				180	1.2	1.2	C	C			
				380	2.0	2.1	C	C			
	ML	1838	17.1	50	0.3	0.3	C	C	ND1	1	Premix replicate test
				180	0.7	0.7	C	C			
				380	1.1	1.1	C	C			
	CL-ML	1857	13.3	50	0.5	0.5	C	C	ND3	1	Final mix
				180	1.3	1.3	C	C			
				380	2.0	2.1	C	C			
	CL-ML	1902	13.3	50	0.6	0.7	C	C	ND3	1	Final mix replicate test
				180	1.3	1.3	C	C			
				380	2.1	2.2	C	C			
BAF: F-3 Northwest corner	CL-ML	1781	16.0	50	0.3	0.3	C	C	ND1	1	Natural soil
				180	0.6	0.6	C	C			
				380	1.0	1.1	C	C			
	CL-ML	1786	16.0	50	0.5	0.5	C	C	ND2	1	Natural soil replicate test
				180	1.1	1.2	C	C			
				380	1.7	1.8	C	C			
	SC-CL	1513	21.0	50	0.3	0.3	C	C	ND1	1	Premix
				180	0.7	0.8	C	C			
				380	1.2	1.3	C	C			
	SC-CL	1512	21.0	50	0.2	0.3	C	C	ND1	1	Premix replicate test
				180	0.5	0.8	C	C			
				380	1.1	1.3	C	C			
	CL-ML	1826	18.4	50	0.3	0.3	C	C	ND1	1	Final mix
				180	0.7	0.9	C	C			
				380	1.3	1.3	C	C			
	CL-ML	1798	18.4	50	0.3	0.3	C	C	ND1	1	Final mix replicate test
				180	0.7	0.7	C	C			
				380	1.1	1.2	C	C			
BAF: F-3 Southwest corner	CL-ML	1788	12.9	50	0.5	0.4	C	C	ND1	1	Natural soil
				180	0.8	1.0	C	C			
				380	1.4	1.6	C	C			
	CL-ML	1794	12.9	50	0.4	0.4	C	C	ND1	1	Natural soil replicate test
				180	0.9	1.0	C	C			
				380	1.5	1.6	C	C			
	SC-SM	1680	15.5	50	0.4	0.3	C	C	ND1	1	Premix
				180	0.8	0.8	C	C			
				380	1.3	1.3	C	C			
	SC-SM	1679	15.5	50	0.4	0.4	C	C	ND1	1	Premix replicate test
				180	0.7	0.9	C	C			
				380	1.3	1.4	C	C			
	SC-SM	1741	16.6	50	0.3	0.3	C	C	ND2	1	Final mix
				180	1.0	1.0	C	C			
				360	2.0	2.0	C	C			
	SC-SM	1745	16.6	50	0.3	0.3	C	C	ND1	1	Final mix replicate test
				180	0.7	0.7	C	C			
				380	1.2	1.2	C	C			
BAF: F-4 North end	CL	1794	13.5	50	0.4	1.1	CL	CL	D1	3	Natural soil
				180							
				380							

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APPENDIX I - Continued
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Placement d (kg/m³)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
	CL	1904	13.5	50 180 380	0.6 •	1.1	CL	CL	D1	3	Natural soil replicate test
	CL	1563	19.1	50 180 380	0.3 0.7 1.2	0.3 0.8 1.2	C C C	C C C	ND1	1	Premix
	CL	1608	19.1	50 180 380	0.3 0.8 1.3	0.3 0.8 1.3	C C C	C C C	ND1	1	Premix replicate test
	CL	1750	17.3	50 180 380	0.5 1.1 1.7	0.5 1.1 1.8	C C C	C C C	ND2	1	Final mix
	CL	1751	17.3	50 180 380	0.2 1.0 1.6	0.1 1.0 1.6	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-4 South end	CL	1934	9.3	50 180 380	0.5	1.1	CL	CL	D1	4	Natural soil
	CL	1937	9.3	50 180 380	0.4	1.1	CL	CL	D1	4	Natural soil replicate test
	CL	1743	12.0	50 180 380	0.3 0.7 1.1	0.3 0.7 1.1	C C C	C C C	ND1	1	Premix
	CL	1750	12.0	50 180 380	0.3 0.8 1.2	0.3 0.8 1.3	C C C	C C C	ND1	1	Premix replicate test
	SC	1696	17.5	50 180 380	0.4 0.9 1.9	0.4 1.0 2.0	C C C	C C C	ND2	1	Final mix replicate test
	SC	1666	17.5	50 180 380	0.4 0.9 2.0	0.4 1.0 2.0	C C C	C C C	ND2	1	Final mix replicate test
BAF: F-5 Southwest corner	CL-ML	1724	8.5	50 180 380	0.4 1.0 1.6	0.4 1.0 2.3	C SC CL	C SC CL	ND2	3	Natural soil
	CL-ML	1724	8.5	50 180 380	0.5 1.2 2.2	0.5 1.5 2.5	C SC CL	C CL CL	ND3	3	Natural soil replicate test
	CL-ML	1735	12.4	50 180 380	0.4 0.9 1.3	0.3 0.9 1.4	C C C	C C C	ND1	1	Premix
	CL-ML	1711	12.4	50 180 380	0.4 0.9 1.4	0.4 0.9 1.4	C C C	C C C	ND1	1	Premix replicate test
	SC	1695	19.2	50 180 380	0.4 1.0 1.5	0.4 1.0 1.5	C C C	C C C	ND1	1	Final mix
	SC	1705	19.2	50 180 380	0.4 0.9 1.6	0.4 1.0 1.6	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-5 Northeast corner	SC-CL	1865	13.5	50 180 380	0.4 0.8 1.3	0.3 0.8 1.3	C C C	C C C	ND1	3	Natural soil
	SC-CL	1879	13.5	50 180 380	0.3 0.8 1.3	0.3 0.8 1.3	C C C	C C C	ND1	3	Natural soil replicate test
	SM	1524	23.7	50 180 380	0.5 1.1 1.7	0.5 1.1 1.7	C C C	C C C	ND2	1	Premix
	SM	1526	23.7	50 180 380	0.4 1.0 1.7	0.4 1.0 1.7	C C C	C C C	ND2	1	Premix replicate test
	SC-SM	1725	17.9	50 180 380	0.5 1.1 1.7	0.5 1.1 1.8	C C C	C C C	ND2	1	Final mix
	SC-SM	1723	17.9	50 180 380	0.5 1.0 1.6	0.4 1.0 1.6	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-6 Northwest corner	CL	1524	12.7	50 180 380	0.3 0.6 1.0	0.3 0.7 1.1	C C C	C C C	ND1	3	Natural soil
	CL	1511	12.7	50 180 380	0.3 0.5 1.0	0.3 0.5 0.9	C C C	C C C	ND1	3	Natural soil replicate test

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APPENDIX I - Continued
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Pinhole test data summary: Placement d (kg/m³)	Placement w (%)	Head (mm)	Q_1 (mL/s)	Q_2 (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
	SC-CL	1410	18.8	50 180 380	0.3 0.8 1.3	0.3 0.8 1.3	C C C	C C C	ND1	1	Premix
	SC-CL	1412	18.8	50 180 380	0.2 0.7 1.3	0.2 0.8 1.3	C C C	C C C	ND1	1	Premix replicate test
	SC	1627	21.6	50 180 380	0.3 0.6 1.0	0.3 0.6 1.0	C C C	C C C	ND1	1	Final mix
	SC	1673	21.6	50 180 380	0.4 1.0 1.9	0.4 1.2 2.0	C C C	C C C	ND2	1	Final mix replicate test
BAF: F-6 Southeast corner	CL	1744	10.8	50 180 380	0.3 0.6 1.0	0.3 0.6 1.0	C C C	C C C	ND1	1	Natural soil
	CL	1736	10.8	50 180 380	0.5 0.9 1.5	0.4 0.9 1.5	C C C	C C C	ND1	1	Natural soil replicate test
	SC-CL	1520	21.4	50 180 380	0.3 0.8 1.3	0.3 0.8 1.3	C C C	C C C	ND1	1	Premix
	SC-CL	1525	21.4	50 180 380	0.3 0.7 1.2	0.3 0.7 1.2	C C C	C C C	ND1	1	Premix replicate test test
	CL	1694	19.9	50 180 380	0.4 0.8 1.3	0.4 0.9 1.4	C C C	C C C	ND1	1	Final mix
	CL	1686	19.9	50 180 380	0.4 0.8 1.3	0.4 0.9 1.4	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-7 Center	CL-ML	1849	10.1	50 180 380	0.3 0.7 1.3	0.4 0.8 1.3	C C C	C C C	ND1	1	Natural soil
	CL-ML	1884	10.1	50 180 380	0.2 0.5 0.9	0.2 0.6 0.9	C C C	C C C	ND1	1	Natural soil replicate test
	SC-SM	1779	16.7	50 180 380	0.6 1.4 2.7	0.5 1.5 2.4	C C C	C C C	ND3	1	Premix
	SC-SM	1817	16.7	50 180 380	0.5 1.1 1.9	0.5 1.1 2.0	C C C	C C C	ND2	1	Premix replicate test
	SC-SM	1855	13.7	50 180 380	0.3 0.8 1.2	0.3 0.8 1.2	C C C	C C C	ND1	1	Final mix
	SC-SM	1846	13.7	50 180 380	0.3 0.9 1.2	0.4 0.9 1.3	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-8 Southeast corner	CL	1765	15.8	50 180 380	0.3 2.0	0.8 2.4	SC	SC	ND4	3	Natural soil
	CL	1765	15.8	50 180 380	0.3 2.6	0.9 2.4	SC SC	SC SC	ND4	3	Natural soil replicate test
	CL	1620	17.1	50 180 380	0.2 0.6 1.0	0.2 0.6 1.1	C C C	C C C	ND1	1	Premix
	CL	1628	17.1	50 180 380	0.4 0.8 1.3	0.4 0.9 1.3	C C C	C C C	ND1	1	Premix replicate test
	SC	1472	26.3	50 180 380	0.4 0.7 1.2	0.4 0.8 1.3	C C C	C C C	ND1	1	Final mix
	SC	1486	26.3	50 180 380	0.3 0.5 0.9	0.3 0.7 1.2	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-8 Northwest corner	CL	1776	13.5	50 180 380	0.4	1.2	CL	CL	D1	4	Natural soil
	CL	1780	13.5	50 180 380	0.4	1.2	CL	CL	D1	4	Natural soil replicate test
	SC	1510	22.4	50 180 380	0.2 0.4 1.1	0.2 0.4 1.1	C C C	C C C	ND1	1	Premix

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APPENDIX I - Continued
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Pinhole test data summary: Placement d (kg/m³)	Placement w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
	SC	1507	22.4	50 180 380	0.2 0.7 1.1	0.2 0.7 1.2	C C C	C C C	ND1	1	Premix replicate test
	CL	1619	20.3	50 180 380	0.3 0.8 1.3	0.3 0.8 1.2	C C C	C C C	ND1	1	Final
	CL	1685	20.3	50 180 380	0.3 0.7 1.2	0.3 0.6 1.1	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-9 Northwest corner	CL	1970	10.5	50 180 380	0.6	1.0	SC	SC	D2	3	Natural soil
	CL	1971	10.5	50 180 380	0.5	1.0	SC	SC	D2	3	Natural soil replicate test
	CL	1311	24.5	50 180 380	0.4 1.0 1.5	0.4 1.0 1.6	C C C	C C C	ND1	1	Premix
	CL	1313	24.5	50 180 380	0.2 0.7 1.1	0.2 0.7 1.1	C C C	C C C	ND1	1	Premix replicate test
	CL-ML	1705	16.9	50 180 380	0.3 0.8 1.4	0.3 0.9 1.4	C C C	C C C	ND1	1	Final mix
		1705	16.9	50 180 380	0.5 0.9 1.5	0.5 1.0 1.5	C C C	C C C	ND1	-	Final mix
BAF: F-9 Southeast corner	SC	1770	13.6	50 180 380	0.3	1.0	SC	SC	D2	3	Natural soil
	SC	1746	13.6	50 180 380	0.3	1.3	SC	SC	D2	3	Natural soil replicate test
	SM	1627	19.8	50 180 380	0.5 1.1 1.8	0.5 1.1 1.8	C C C	C C C	ND1	1	Final mix
	SM	1627	19.8	50 180 380	0.7 1.1 1.8	0.5 1.1 1.8	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-10 Southeast corner	CL	1894	11.8	50 180 380	0.2 1.6	0.4 2.3	SC SC	SC SC	ND4	1	Natural soil
	CL	1904	11.8	50 180 380	0.3 0.8 1.3	0.3 0.9 1.3	C C C	C C C	ND1	1	Natural soil replicate test
	SM-SC	1612	22.9	50 180 380	0.4 0.8 1.2	0.4 0.8 1.2	C C C	C C C	ND1	1	Premix
	SM-SC	1567	22.9	50 180 380	0.3 0.6 1.1	0.3 0.6 1.1	C C C	C C C	ND1	1	Premix replicate test
	SC	1517	21.2	50 180 380	0.3 0.7 1.2	0.3 0.7 1.2	C C C	C C C	ND1	1	Final mix
	SC	1497	21.2	50 180 380	0.3 0.6 1.0	0.3 0.6 1.0	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-10 Northwest corner	CL	1736	16.3	50 180 380	0.4 1.1 1.6	0.6 1.1 1.6	C C C	C C C	ND1	3	Natural soil
	CL	1726	16.3	50 180 380	0.5 0.8	0.5 1.5			Test stopped not classified (prob. ND4)		Natural soil replicate test
	SC-SM	1613	19.8	50 180 380	0.5 1.0 1.6	0.5 1.0 1.6	C C C	C C C	ND1	1	Premix
	SC-SM	1605	19.8	50 180 380	0.4 0.9 1.3	0.4 0.9 1.3	C C C	C C C	ND1	1	Premix replicate data
	SC	1667	17.4	50 180 380	0.3 0.7 1.1	0.3 0.7 1.1	C C C	C C C	ND1	1	Final mix
	SC-CL	1640	17.4	50 180 380	0.3 0.7 1.2	0.3 0.7 1.2	C C C	C C C	ND1	1	Final mix replicate data

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APPENDIX I - Continued
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Pinhole test data summary: Placement d (kg/m³)	Placement w (%)	Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
BAF: F-10 Center	CL	1726	21.0	50	0.4	0.4	C	C	ND1	1	Natural soil
				180	0.8	0.9	C	C			
				380	1.3	1.3	C	C			
	CL	1712	21.0	50	0.3	0.3	C	C	ND1	1	Natural soil - replicate test
				180	0.7	0.8	C	C			
				380	1.3	1.3	C	C			
	CL	1668	18.7	50	0.5	0.5	C	C	ND1	1	Premix
				180	1.0	1.0	C	C			
				380	1.7	1.7	C	C			
	CL	1641	18.7	50	0.4	0.3	C	C	ND1	1	Premix replicate test
				180	0.6	0.8	C	C			
				380	1.1	1.2	C	C			
	CL	1672	21.5	50	0.2	0.2	C	C	ND1	1	Final mix
				180	0.7	0.7	C	C			
				380	1.2	1.2	C	C			
	CL	1672	21.5	50	0.1	0.1	C	C	ND1	1	Final mix replicate test
				180	0.3	0.3	C	C			
				380	1.0	1.0	C	C			
BAF: F-11 Northwest corner	CL-ML	1864	9.2	50	0.3	0.3	C	C	ND1	3	Natural soil
				180	0.5	0.8	C	C			
				380	1.0	1.2	C	C			
	CL-ML	1813	9.2	50	0.4	0.4	C	C	ND1	3	Natural soil replicate test
				180	0.9	0.9	C	C			
				380	1.5	1.5	C	C			
	SC	1859	12.9	50	0.3	0.3	C	C	ND1	1	Premix
				180	0.8	0.7	C	C			
				380	1.2	1.2	C	C			
	SC	1850	12.9	50	0.5	0.5	C	C	ND1	1	Premix replicate test
				180	0.9	0.9	C	C			
				380	1.2	1.2	C	C			
	SM-SC	1798	15.2	50	0.3	0.3	C	C	ND1	1	Final mix
				180	0.8	0.8	C	C			
				380	1.2	1.2	C	C			
	SM-SC	1796	15.2	50	0.3	0.3	C	C	ND1	1	Final mix replicate test
				180	0.8	0.8	C	C			
				380	1.2	1.2	C	C			
BAF: F-11 Southeast corner	CL-ML	1911	14.5	50	0.6	0.6	C	C	ND2	1	Natural soil
				180	1.2	1.3	C	C			
				380	1.9	2.0	C	C			
	CL-ML	1933	14.5	50	0.4	0.4	C	C	ND2	1	Natural soil replicate test
				180	1.1	1.1	C	C			
				380	1.8	1.8	C	C			
	SM-SC	1725	18.1	50	0.3	0.3	C	C	ND1	1	Premix
				180	0.7	0.7	C	C			
				380	1.1	1.2	C	C			
	SM-SC	1739	18.1	50	0.1	0.3	C	C	ND1	1	Premix replicate test
				180	0.7	0.7	C	C			
				380	1.2	1.2	C	C			
	SM	1758	16.6	50	0.4	0.4	C	C	ND1	1	Final mix
				180	0.8	0.8	C	C			
				380	1.4	1.4	C	C			
	SM	1738	16.6	50	0.4	0.4	C	C	ND1	1	Final mix replicate test
				180	0.9	0.9	C	C			
				380	1.4	1.4	C	C			
BAF: F-11B Southeast corner	CL	1816	16.6	50	0.3	0.3	C	C	ND1	1	Natural soil
				180	0.7	0.7	C	C			
				380	1.1	1.1	C	C			
	CL	1819	16.6	50	0.2	0.3	C	C	ND1	1	Natural soil replicate test
				180	0.7	0.7	C	C			
				380	1.2	1.2	C	C			
	SC	1517	21.6	50	0.3	0.3	C	C	ND1	1	Premix
				180	0.8	0.8	C	C			
				380	1.3	1.3	C	C			
	SC	1562	21.6	50	0.2	0.3	C	C	ND1	1	Premix replicate test
				180	0.7	0.7	C	C			
				380	1.2	1.2	C	C			
BAF: F-11B Northwest corner	CL	1718	19.0	50	0.2	0.3	C	C	ND1	2	Natural soil
				180	0.6	0.7	C	C			
				380	0.9	1.0	C	C			
	CL	1712	19.0	50	0.2	0.4	C	C	ND2	2	Natural soil replicate test
				180	1.1	1.1	C	C			
				380	1.8	1.8	C	C			
	SC-CL	1685	20.1	50	0.3	0.3	C	C	ND1	1	Premix
				180	0.8	0.8	C	C			
				380	1.3	1.3	C	C			

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APPENDIX I - Continued
MCGEE CREEK DAM - LIME-TREATED SOIL IN BORROW AREA F

Sample identification	Unified soil class.	Placement d (kg/m³)	Placement w (%)	Pinhole test data summary: Head (mm)	Q_i (mL/s)	Q_f (mL/s)	Turbidity* Initial	Turbidity* Final	Classification	Crumb test	Remarks
	SC-CL	1685	20.1	50 180 380	0.3 0.8 1.3	0.3 0.8 1.3			ND1	1	Premix replicate test
BAF: F-12 Southeast corner	CL	1841	13.0	50 180 380	0.2	1.0	CL	CL	D2	4	Natural soil
	CL	1793	13.0	50 180 380	0.2	1.0	CL	CL	D2	4	Natural soil replicate test
	SC	1528	19.2	50 180 380	0.3 0.7 1.1	0.3 0.7 1.1	C C C	C C C	ND1	1	Premix
	SC	1545	19.2	50 180 380	0.4 0.9 1.4	0.4 0.9 1.4	C C C	C C C	ND1	1	Premix replicate test
	SC	1523	28.5	50 180 380	0.4 0.7 1.4	0.4 0.9 1.4	C C C	C C C	ND1	1	Final mix
	SC	1533	28.5	50 180 380	0.3 0.6 1.1	0.3 0.7 1.1	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-12 Northwest corner	CL	1839	16.7	50 180 380	0.2 2.1	0.8 2.5	SC SC	SC SC	ND4	4	Natural soil
	CL	1837	16.7	50 180 380	0.2 2.0	0.6 2.6	SC SC	SC SC	ND4	4	Natural soil replicate test
	SC	1647	21.4	50 180 380	0.3 0.7 1.1	0.3 0.7 1.2	C C C	C C C	ND1	1	Premix
	SC	1647	21.4	50 180 380	0.3 0.7 1.2	0.3 0.7 1.2	C C C	C C C	ND1	1	Premix replicate test
BAF: F-13 Southeast corner	SC-CL	1623	13.3	50 180 380	0.4 0.8 1.4	0.4 0.9 1.4	C C C	C C C	ND1	1	Natural soil
	SC-CL	1631	13.3	50 180 380	0.3 0.7 1.2	0.3 0.8 1.2	C C C	C C C	ND1	1	Natural soil replicate test
	SC-CL	1500	15.3	50 180 380	0.2 0.7 1.1	0.3 0.7 1.1	C C C	C C C	ND1	1	Premix
	SC-CL	1606	15.3	50 180 380	0.3 0.6 1.0	0.3 0.7 1.2	C C C	C C C	ND1	1	Premix replicate test
	SC	1441	27.3	50 180 380	0.3 0.7 1.2	0.3 0.7 1.2	C C C	C C C	ND1	1	Final mix
	SC	1442	27.3	50 180 380	0.4 0.8 1.4	0.3 0.9 1.4	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-13 Northwest corner	CL	1758	13.6	50 180 380	0.4 0.8 1.4	0.4 0.9 1.5	C C C	C C C	ND1	1	Natural soil
	CL	1730	13.6	50 180 380	0.4 0.8 1.2	0.4 0.6 1.4	C C C	C C C	ND1	1	Natural soil replicate test
	CL	1734	17.3	50 180 380	0.3 0.6 1.1	0.3 0.7 1.2	C C C	C C C	ND1	1	Natural soil replicate test
	CL	1718	17.3	50 180 380	0.3 0.7 1.2	0.3 0.8 1.2	C C C	C C C	ND1	1	Final mix replicate test
BAF: F-13 Southwest corner	SC	1183	25.5	50 180 380	0.3 0.7 1.2	0.3 0.8 1.2	C C C	C C C	ND1	1	Premix
	SC	1509	25.5	50 180 380	0.3 0.8 1.1	0.3 0.8 1.3	C C C	C C C	ND1	1	Premix replicate test

* D = Dark/distinctly cloudy CL = Cloudy SC = Slightly cloudy C = Clear

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APPENDIX J
MCGEE CREEK DAM - STOCKPILED LIME-TREATED SOIL

Sample identification	Unified soil class.	Pinhole test data summary: Placement d (lb/ft³)	Placement w (%)	Head (mm)	Q_1 (mL/s)	Q_2 (mL/s)	Turbidity[a] Initial	Turbidity[a] Final	Classification	Crumb test	Remarks
BA-F: F-4 Stockpile	SC	1568	17.2	50	0.2	0.4	C	C	ND2	1	2 percent lime-treated soil cured airtight fo. 22 weeks before test
				180	1.0	1.1	C	C			
				380	1.6	1.7	C	C			
BA-F F-4 Stockpile	SC	1668	16.3	50	0.4	0.4	C	C	ND1	1	Replicate test (see above)
				180	0.8	0.9	C	C			
				380	1.3	1.4	C	C			
BA-F: F-4 Stockpile	SC	1571	9.2	50	0.2	0.2	C	C	ND1	1	2 percent lime-treated soil allowed to air dry for 22 weeks before test
				180	0.5	0.7	C	C			
				380	1.0	1.0	C	C			
BA-F: F-4 Stockpile	SC	1511	9.2	50	0.2	0.2	C	C	ND1	1	Replicate test (see above)
				180	0.7	0.7	C	C			
				380	1.0	1.0	C	C			

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APPENDIX K

PROCEDURE FOR DETERMINING DISPERSIBILITY OF CLAYEY SOILS BY THE PINHOLE TEST METHOD

USBR 5410-XX

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CONTENTS

Part		Page
	Introduction	41
1	Scope	41
2	Auxiliary tests	42
3	Applicable documents	42
4	Summary of method	43
5	Significance and use	43
6	Terminology	44
7	Interferences	44
8	Apparatus	44
9	Reagents and materials	45
10	Precautions	45
11	Sampling, test specimens, and test units	45
12	Calibration and standardization	45
13	Conditioning	46
14	Procedure	46
15	Interpretation of results	50
16	Report	50
	References	51

FIGURES

Figure		
1	USBR pinhole test apparatus (2 sheets)	52
2	Pinhole specimen compaction and erosion data	54
3	Pinhole test flow-rate data	55
4	Pinhole test dispersive grade versus flow rate	56
5	Pinhole specimen compaction and erosion data (typical dispersive soil)	57
6	Pinhole test flow-rate data (typical dispersive soil)	58
7	Pinhole test dispersive grade versus flow rate (typical dispersive soil)	59
8	Pinhole specimen compaction and erosion data (typical nondispersive soil)	60
9	Pinhole test flow-rate data (typical nondispersive soil)	61
10	Pinhole test dispersive grade versus flow rate (typical nondispersive soil)	62

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

USBR 5410. XX*

PROCEDURE FOR

Determining Dispersibility of Clayey Soils
by the Pinhole Test Method

INTRODUCTION

This test procedure is under the jurisdiction of the Geotechnical Branch, code D-1540, Division of Research and Laboratory Services, Engineering and Research Center, Denver, Colorado. The test procedure is issued under the fixed designation USBR 5410. The number immediately following the designation indicates the year of acceptance or the year of last revision.

This test procedure is similar to that outlined in Bureau of Reclamation Report REC-ERC-79-10, pp. 1-8, except for a rewritten, more detailed description of the test procedure, new equipment design features, and new data forms for recording and interpreting results.

1. Scope

1.1 This designation outlines the procedure for determining dispersibility of clayey soils by the pinhole test method.

1.2 Dispersibility, dispersivity, or dispersion refers to the process of clay colloid deflocculation in the presence of water. Deflocculation of clay colloids occurs when the interparticle repulsive forces exceed the attractive forces. These physicochemical forces are very large in relation to the gravity forces on the individual clay particles and, hence, cause the individual particles to go into suspension in the presence of water.

1.3 The pinhole test is a direct, physical method for evaluating the dispersibility of clay soils while water flows through a small pinhole in the soil specimen.

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* This test designation is annotated - XX to indicate preliminary issue of yet to be approved test procedure.

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1.4 The dispersion of clay colloids is observed by cloudiness in the discharge effluent.

1.5 For dispersive soils, the measured flow rate increases as the pinhole diameter enlarges until the hydraulic capacity of the equipment has been reached. For nondispersive soils, the measured flow rate remains constant at each head and the pinhole diameter stays the same throughout the test. A detailed analysis of pinhole equipment hydraulic characteristics for dispersive and nondispersive is presented in reference [1].**

1.6 The test should be conducted only on soils with more than 12 percent minus 0.005-mm particles and with plasticity index greater than or equal to 7, as determined in accordance with test designations USBR 5330, 5350, and 5360.

2. Auxiliary Tests

2.1 USBR Test Designations

2.1.1 USBR 1009, Calibrating Proctor Compaction Molds
2.1.2 USBR 5300, Determining Water Content of Soils by the Oven Method
2.1.3 USBR 5330, Performing Particle Size Analysis of Soils, including Hydrometer Analyses
2.1.4 USBR 5350, Determining Liquid Limit of Soils by the One Point Method
2.1.5 USBR 5360, Determining Plastic Limit and Plasticity Index of Soils
2.1.6 USBR 5400, Determining Dispersibility of Clayey Soils by the Crumb Test Method
2.1.7 USBR 5405, Determining Dispersibility of Clayey Soils by the Double Hydrometer Test Method
2.1.8 USBR 5500, Performing Laboratory Compaction of Soils (Moisture Density Relations)

3. Applicable Documents

3.1 USBR 1009, Calibrating Proctor Compaction Molds
3.2 USBR 1012, Calibrating Balances and Scales
3.3 USBR 1025, Calibrating Sieves and Screens
3.4 USBR 5300, Determining Water Content of Soils by the Oven Method
3.5 USBR 5330, Performing Particle Size Analyses of Soils, including Hydrometer Analyses
3.6 USBR 5350, Determining Liquid Limit of Soils by the One Point Method
3.7 USBR 5360, Determining Plastic Limit and Plasticity Index of Soils
3.8 USBR 5400, Determining Dispersibility of Clayey Soils by the Crumb Test Method
3.9 USBR 5405, Determining Dispersibility of Clayey Soils by the Double Hydrometer Test Method

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** Numbers in brackets indicate references.

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3.10 USBR 5500, Performing Laboratory Compaction of Soils (Moisture Density Relations)
3.11 USBR 5510, Performing Laboratory Compaction of Soils (Harvard Miniature)
3.12 USBR 9100, List of Laboratory Equipment

4. Summary of Method

4.1 A 25-mm-long by 35-mm-diameter cylindrical soil specimen is secured between two end plates and connected to a constant head tank. The intake end plate incorporates a 1.5-mm-diameter hole that serves as a centering guide for punching a 1.0-mm-diameter hole through the 25-mm-long soil specimen. The 1.0-mm-diameter hole, the "pinhole" for which the test is named, is made with a 6-inch aircraft extension drill. Water is percolated through this pinhole under heads of 50, 180, and 380 mm, and the flow rate and effluent turbidity are recorded. For nondispersive soils, the pinhole diameter remains unchanged throughout the test, the discharge effluent remains clear, and the measured flow rate remains constant at each head. For dispersive soils, the pinhole diameter increases throughout the test, the discharge effluent contains easily visible clay colloids in suspension, and the flow rate at the 50-mm head increases rapidly during the first 10 minutes of the test.

5. Significance and Use

5.1 The pinhole test has become the generally accepted reference test for identifying dispersive clays.

5.2 Water flow through the pinhole in the soil specimen simulates the water flow through a crack in the impervious core of a dam or other structure. The 50-, 180-, and 380-mm heads cause flow velocities ranging from approximately 30 to 160 cm/s at hydraulic gradients ranging from approximately 2 to 15.

5.3 The pinhole test was originally developed, in part, by using clayey soils selected from field sites with known erodible and erosion resistant characteristics. The results of tests conducted on hundreds of specimens indicate that the pinhole test gives the best correlation with erosional performances of soils in nature. Other indirect tests such as the crumb test (USBR 5400), double hydrometer (USBR 5405), and soil-pore water cation and zeta potential analyses are also used as dispersive clay identification tests. However, the results of those tests are less effective than the pinhole test for identifying dispersive clays.

5.4 The pinhole test has been successfully used on the McGee Creek Dam and Central Arizona Projects to identify dispersive and nondispersive soils for selective use in constructing project features.

5.5 The pinhole test is generally used as the control test in research programs for developing new or improved techniques for identifying dispersive soils.

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5.6 The pinhole test, as originally developed by Sherard [2], was intended as a qualitative test which emphasized visually observing the discharge water. As a result of USBR research efforts and operating experience, a quantitative evaluation method was developed and documented [1]. The quantitative method emphasizes the measured flow rate as the primary test evaluation criterion. This test procedure is adapted from references [1 and 2].

6. Terminology

6.1 Dispersive Clay - clay colloids that deflocculate in the presence of [illegible]ause the physicochemical repulsive forces on the particles exce[illegible] attractive forces. Dispersive clay colloids are easily detached from one another, and the individual particles go into suspension in the presence of water.

6.2 Turbidity - visual cloudiness caused by suspended clay colloids in the discharge water collected during the pinhole test.

6.3 Cations - positively charged ions, usually Na, Ca, Mg, and K are the major cations available in a soil-water system.

7. Interferences

7.1 The presence of significant amounts of fine and medium size sand particles in the pinhole test specimen can affect the test results. The larger sand particles may not completely pass through the pinhole specimen after separating from the surface of the pinhole. When this occurs, the flow rate may be reduced and some excessive local scour erosion may occur along the pinhole at the location where the sand particles were separated and/or deposited. Later in the test, the water velocity at the 180- or 380-mm head may be sufficient to move those sand particles and clear up blockages that may have occurred. This phenomenon can only be determined at the conclusion of the test by inspecting the final shape of the eroded pinhole and observing fine or medium sand accumulated at the downstream end of the specimen or in the discharge end plate.

8. Apparatus

8.1 USBR 9100, List of Laboratory Equipment

8.1.1 Balance, Item 040.

8.2.2 Sieve, U.S. Standard Series Nos. 4 and 10 Item 640.

8.2 Pinhole specimen compaction and test apparatus (fig. 6K-1) consisting of:

8.2.1 Modified Harvard miniature compaction mold stand, collar, pinhole specimen mold and specimen mold adapter.

8.2.2 Intake and Discharge End Plates with wing nut and bolt assembly.

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8.3 Miscellaneous Items.

8.3.1 Harvard Miniature Compaction Tamper with 20-lb (6.8-kg) spring.

8.3.2 Dowel, wood or plastic, used for leveling loose soil lifts in the pinhole specimen mold.

9. Reagents and Materials

9.1 Use distilled water for preparing the compacted soil specimen and for percolating through the hole in the test specimen.

9.2 The use of tap water or water from other sources is not recommended. It has been shown that distilled water has the greatest potential for exchanging absorbed cations from the clay mineral surfaces [2]. Water with impurities, i.e., water containing cations, anions, and ion pairs in solution, will generally cause a reduced degree of dispersion. The use of distilled water represents the worst case situation for laboratory evaluation of soil dispersibility.

10. Precautions

10.1 Safety Precaution

10.1.1 There are no special safety precautions required.

10.2 Technical Precautions

10.2.1 The test specimen should be prepared and compacted as quickly as possible to avoid unrecorded moisture loss that would reduce placement dry density and moisture content.

11. Sampling, Test Specimens, and Test Units

11.1 Obtain approximately 400 grams of representative minus No. 4 soil in accordance with USBR 5205.

Note 1: 400 grams of soil are required to provide sufficient material for concurrently performing the crumb and double hydrometer tests, USBR 5400 and USBR 5405, respectively, in addition to the pinhole. USBR 5400, 5405, and 5410 generally constitute the dispersive clay test series.

11.2 Preserve the soil specimen at natural water content, if possible, or allow to air dry only. Oven-dried soil should not be used because of the possible effects on changing the dispersion potential of some clay minerals.

11.3 Obtain approximately 150 grams of minus No. 10 soil.

12. Calibration and Standardization

12.1 Check to see that the pinhole specimen mold is currently calibrated in accordance with USBR 1009, Calibrating Proctor Compaction Mold Volumes.

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If the calibration is not current, the calibration procedures should be performed before using the pinhole specimen mold.

12.2 Check to see that the balance to be used for weighing the soil specimen is calibrated in accordance with USBR 1012, Calibrating Balances and Scales. If the calibration is not current, the calibration procedures shuld be performed before using the balance.

12.3 Check to see that the sieves to be used for preparing the soil specimen are calibrated in accordance with USBR 1025, Calibrating Sieves and Screens. If the calibration is not current, the calibration procedures should be performed before using the sieves.

13. Conditioning

13.1 Determine the Proctor maximum dry density and optimum water content of the soil by performing USBR 5500, Performing Laboratory Compaction of Soils, or by consulting the engineer or supervisor in charge.

13.2 Determine 98 percent Proctor maximum dry density and the moisture content 2 percent dry of optimum water content.

Note 2: Pinhole test specimens are generally compacted at 98 percent Proctor maximum dry density and 2 percent dry of optimum water content. Variations should be approved by the engineer or supervisor in charge.

13.3 Determine the water content of a representative portion of the 150-gram soil sample by performing USBR 5300, Determining Water Content of Soils by the Oven Method.

13.4 Calculate the amount of water to be added to the remaining soil sample to increase the water content to the required value.

13.5 Allow the moist soil sample to mellow for a minimum of 16 hours to ensure uniform distribution of water throughout the sample.

13.6 Determine the water content of a representative portion of the 150-gram soil sample by performing USBR 5300, Determining Water Content of Soils by the Oven Method.

13.7 Repeat paragraphs 13.4 through 13.6 until the measured water content is within ±1 percent of the desired water content.

14. Procedure

14.1 Select the pinhole specimen mold to be used for compacting the test specimen. Record its calibrated volume.

14.2 Determine the weight of moist soil that is required to achieve the desired placement density in the selected pinhole specimen mold using figure X1.1.

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14.3 Place the container that will hold the moist soil on the scale, and record its weight or tare the scale to zero.

14.4 Add the total amount of moist soil required to the container.

14.5 Divide the total amount of moist soil by 5, the required number of lifts. This is the amount of soil required for each lift.

14.6 Remove the amount of moist soil required for the first lift and place it into the assembled pinhole specimen mold, mold collar, and compaction stand (fig. 6K-1) and gently level the surface using the wood or plastic dowel. Record the total weight of moist soil remaining in the container.

14.7 Compact the soil using 25 tamps of the Harvard Miniature Spring-Loaded Tamper. Distribute the tamper to ensure 100 percent coverage of the soil specimen.

14.8 Remove the amount of moist soil required for a second lift, place it into the mold and gently level the surface with the dowel. Record the total weight of moist soil remaining in the container.

14.9 Repeat paragraphs 14.6 through 14.8 until the container has been completely emptied.

14.10 After the final lift is compacted, carefully remove the pinhole specimen mold from the collar and mold assembly.

> Note 3: An alternate compaction procedure, adapted from reference [3], may be used. It eliminates weighing the soil required for each lift. For this procedure, use the 2 slightly heaping teaspoons of soil per lift, with 3 total lifts required and 25 tamps per lift. The proper amount of soil for each lift may vary with different soils. Additional trials may be required to develop the technique for selecting the proper amount of soil.

14.11 Inspect the top of the specimen (the most recently compacted surface) to ensure that the soil completely fills the mold with little or no excess soil.

14.12 Carefuly trim excess soil from the top of the specimen using a straightedge or fine-tooth hacksaw blade and brush all soil from the mold surfaces.

14.13 Weigh the specimen and mold assembly and determine the dry density. If the actual placement dry density is greater than or equal to the desired density (usually 98 percent Proctor maximum), retain the test specimen. If the actual placement density is too low, the specimen must be rejected and another specimen prepared in accordance with paragraphs 14.2 through 14.2, using an additional five tamps per lift.

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14.14 Record the placement density obtained, the number of tamps per lift, and the number of lifts required for final specimen compaction using figure 6-K2.

14.15 Place the top of the specimen and mold in the intake end plate. Place a No. 10 screen on the bottom of the specimen and press on the discharge end plate. Close the assembly using the bolts and wing nuts. Alternately and lightly tighten each wing nut making the end plates close evenly. The watertight seal is maintained by the O-ring seals in the end plates, not the torque on the wing nuts.

14.16 Carefully punch the pinhole into the specimen, from the intake end plate completely through to the discharge end plate, using a No. 40 6-inch drill and pliers. When the drill appears through the discharge end plate, pull it completely through, using the pliers in one slow continuous motion to ensure that a uniform, 1.0-mm-diameter pinhole is obtained.

Note 4: Occasionally, the path of the drill is changed by sand particles so that it hits the screen or face of the discharge end plate. When this occurs, do not force the drill. Instead, remove the discharge end plate and determine if the drill hit the screen or the discharge end plate. If the drill hit the screen, move the screen slightly, reattach the discharge end plate and continue punching the pinhole. If the drill hit the end plate, carefully pull the drill through the specimen and the screen with the pliers and reattach the discharge end plate.

14.17 After the pinhole is punched, remove the screen from the bottom of the specimen and reassemble the discharge end plate to the intake end plate and specimen.

14.18 Close the outlet valve of the constant head tank, fill with distilled water, and secure rubber stopper in the top of the tank. Connect the constant head tank outlet to the intake end plate. Connect the standpipe tube to the vent in the intake end plate. Secure the assembled end plates and mold in the horizontal position.

14.19 Open the bleed valve in the head tank outlet line until the water level in the air intake tube lowers to the bottom of the tube and air enters the head tank through the air intake tube.

14.20 Start the test by slowly opening the head tank outlet valve and raising the position of the head tank until the head water reaches the 50-mm mark on the standpipe tube.

14.21 Record the time at the start of the test using figure 6K-3.

14.22 Measure the flow rate in mL/s using a 100-mL graduate and a stopwatch. Collect the effluent for 60-second intervals, record the amount of milliliters collected, and divide by 60 to determine mL/s.

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14.23 Observe the cloudiness (turbidity) of the effluent and record for each 60-second interval as either dark, cloudy, slightly cloudy, or clear. Observe the effluent through the side of the graduate and from the top of the graduate. Clear effluent can only be judged from the top view.

NOTE 5: If flow does not begin at the start of the test or if flow stops during the test, stop the test, remove the assembled apparatus, repunch the pinhole, and continue the test.

14.24 Continue the test for 5 minutes at the 50-mm head. If the flow is dark or cloudy, and flow rates have gradually increased to 1.0-1.4 mL/s, the test is complete.

14.24.1 Dismantle the apparatus and determine the final size of the eroded pinhole by either extruding the specimen and splitting it longitudinally or observing the pinhole from each end. The final hole diameter will generally be two or more times the original 1.0-mm-diameter.

14.24.2 Classify the soil as dispersive, D1.

14.25 If the flow at the 50-mm head is dark, cloudy, slightly cloudy, or clear at the end of 5 minutes and the flow rate is less than 1.0 mL/s, continue the test for an additional 5 minutes, at the 50 mm head.

14.25.1 If the flow at the 50-mm head is dark, cloudy, or slightly cloudy and the flow rate has increased to 0.80-1.4 mL/s, the test is complete.

14.25.2 Classify the soil as dispersive - D2 - if the flow rate is 1.0-1.4 mL/s. Classify the soil as intermediate - ND4 - if the flow rate is 0.80-1.0 mL/s.

14.26 If the flow at the 50-mm head is clear or slightly cloudy and the flow rate is 0.20-0.80 mL/s, raise the head to 180 mm and continue the test for an additional 5 minutes.

14.26.1 If the flow at the 180-mm head is cloudy or slightly cloudy and the flow rate has increased to 1.2-2.8 mL/s, the test is complete.

14.26.2 Dismantle the apparatus and determine the final size of the eroded pinhole by either extruding the specimen and splitting it longitudinally or observing the pinhole from each end. The final hole diameter will generally be 1.5 to 2 times the original 1.0-mm diameter.

14.26.3 Classify the soil as intermediate - ND4 - if the flow rate is 2.0-2.8 mL/s. Classify the soil as intermediate - ND3 - if the flow rate is 1.2-2.0 mL/s.

14.27 If the flow at the 180-mm head is clear or slightly cloudy and the flow rate is 0.6-1.2 mL/s, raise the head to 380 mm and continue the test for an additional 5 minutes.

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14.28 If the flow at the 380-mm head is clear or slightly cloudy and the flow rate is 0.80-2.5 mL/s, the test is complete.

14.28.1 Dismantle the apparatus and determine the final size of the pinhole by either extruding the specimen and splitting it longitudinally or observing the pinhole from each end. The final hole diameter will generally be 1 to 1.5 times the original 1.0-mm diameter.

14.28.2 Classify the soil as nondispersive - ND2 - if the flow rate is 1.6-2.5 mL/s. Classify the soil as nondispersive - ND1 - if the flow rate is 0.80-1.6 mL/s.

15. Interpretation of Results

15.1 For each 60 second flow measurement interval, record the water turbidity, the volume of water collected (in mL), calculate the flow rate in mL/s, and plot the flow rate on figure 6K-4.

16. Report

16.1 The pinhole test report includes the following:

16.1.1 Project/feature name.

16.1.2 Soil samples index number or depth and location of sample.

16.1.3 Water content of sample before sample preparation.

16.1.4 Water content and placement dry density of compacted specimen including number of lifts and number of tamps per lift.

16.1.5 Hydraulic head in millimeters, turbidity of flow at each measurement interval, and flow rate in mL/s at each measurement interval.

16.1.6 Description, sketch, or photograph of final pinhole at the completion of the test.

16.1.7 Final dispersive grade classifications, D1, D2, ND4, ND3, ND2, and ND1.

16.2 Example and blank data sheets for dispersive and nondispersive pinhole test results are given on figures 6K-2 through 6K-10.

16.3 Completing figures 6K-2, 6K-3, and 6K-4 satisfies all the requirements of the pinhole test report.

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REFERENCES

[1] Acciardi, Raymond G., "Quantification of Pinhole Test Equipment Hydraulic Characteristics," Technical Report REC-ERC-82-15, Bureau of Reclamation, Denver, Colorado, September 1982.

[2] Sherard, James L. et al., "Pinhole Test for Identifying Dispersive Soils," Journal of the Geotechnical Division, ASCE, vol. 102, No. GT1, Proc. Paper No. 11846, pp. 69-85, January 1976.

[3] Soiltest Inc., Operating Instructions for Harvard Miniature Compaction Apparatus, Model No. CN-435, May 1977.

USBR 1009, Calibrating Proctor Compaction Molds
USBR 5300, Determining Water Content of Soils by the Oven Method
USBR 5330, Performing Particle Size Analyses of Soils, including Hydrometer Analyses
USBR 5350, Determining Liquid Limit of Soils by the One Point Method
USBR 5360, Determining Plastic Limit and Plasticity Index of Soils
USBR 5400, Determining Dispersibility of Clayey Soils by the Crumb Test Method
USBR 5405, Determining Dispersibility of Clayey Soils by the Double Hydrometer Test Method
USBR 5500, Performing Laboratory Compaction of Soils (Moisture Density Relations)
USBR 5510, Performing Laboratory Compaction of Soils (Harvard Miniatures)
USBR 9100, List of Laboratory Equipment

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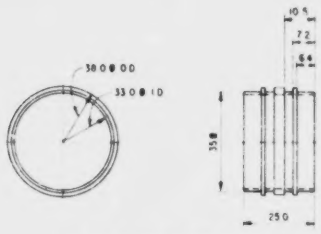
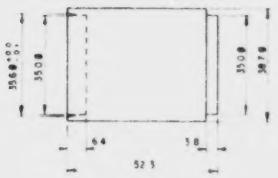
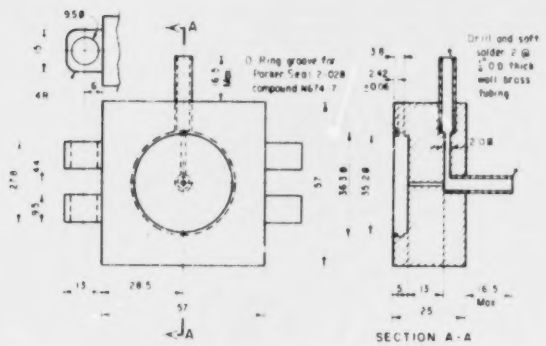


PINHOLE SPECIMEN MOLD



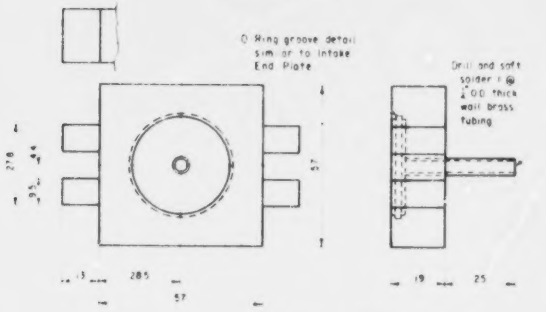
SPECIMEN MOLD ADAPTER

NOTES
1. All dimensions are in millimeters.
2. ø indicates diameter.
3. Stainless steel stock required.
4. Specimen Mold Adapter is designed for use with Soiltest, Inc. Part No. CN 428, Mold Holder. The adapter allows the Standard Havard Miniature Compaction Mold Holder (CN 428) to be used with the U.S.B.R. Pinhole Specimen Mold.



INTAKE END PLATE

SECTION A-A



DISCHARGE END PLATE

NOTES
1. All dimensions are in millimeters.
2. ø indicates diameter.
3. Brass stock required.

Figure K-1. – USBR pinhole test apparatus (sheet 1 of 2).

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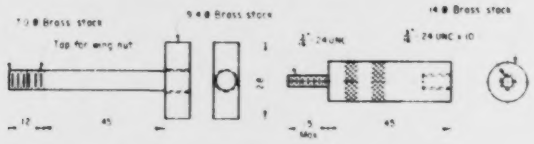
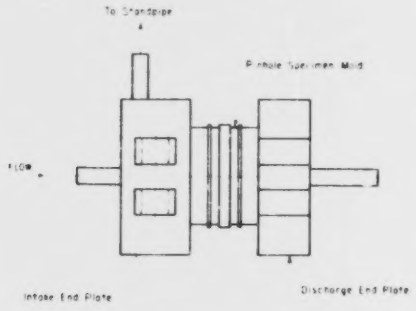
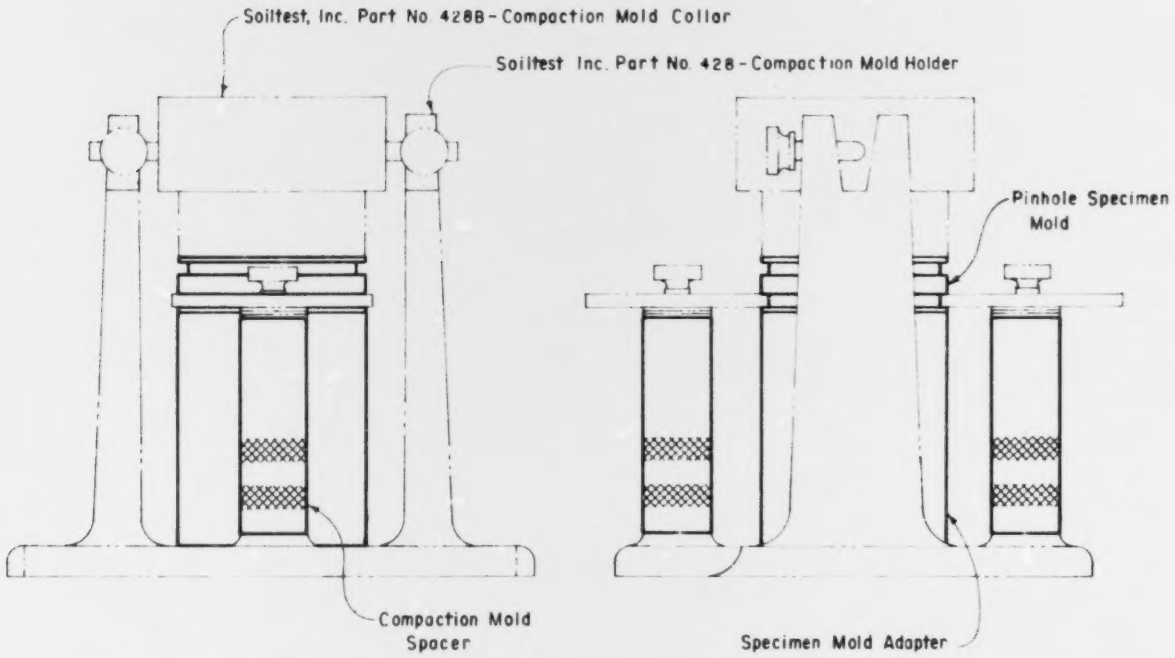


WING NUT & BOLT ASSEMBLY
(END PLATE CLAMPING DEVICE)

COMPACTION MOLD SPACER



PINHOLE TEST APPARATUS - ASSEMBLY DRAWING
(WING NUT & BOLT ASSEMBLY OMITTED FOR CLARITY)


Soiltest, Inc. Part No. 428B - Compaction Mold Collar
Soiltest Inc. Part No. 428 - Compaction Mold Holder
Pinhole Specimen Mold
Compaction Mold Spacer
Specimen Mold Adapter

PINHOLE SPECIMEN COMPACTION APPARATUS - ASSEMBLY DRAWING
(COMMERCIALLY AVAILABLE ITEMS SHOWN IN PHANTOM LINES)

Figure K-1. – USBR pinhole test apparatus (sheet 2 of 2).

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PINHOLE TEST

PROJECT _____ TESTED BY _____ DATE _____
FEATURE _____ COMPUTED BY _____ DATE _____
SAMPLE NO. _____ CHECKED BY _____ DATE _____

MOLD NO. _____ VOLUME OF MOLD _____ cm^3 WEIGHT OF MOLD _____ gms

COMPACTION DATA FOR REMOLDED SPECIMENS

1. Dry Density (pcf ÷ 0.01602) = g/cm^3 _____ g/cm^3
2. Water Content _____ g
3. Initial Dry Wt. _____ g
4. Initial Wet Wt. _____ g
5. Wet Wt. ÷ 5 layers _____ g
6. Wet Wt. + Container _____ g _____ g
7. Total Wt. Less Each Layer
   (1) _____ g
   (2) _____ g
   (3) _____ g
   (4) _____ g
   (5) _____ g

ACTUAL OBTAINED DENSITY OF REMOLDED OR UNDISTURBED SPECIMEN

8. Wet Wt. + Mold _____ g
9. Wt. of Mold _____ g
10. Wt. of Wet Soil _____ g
11. Wet Density _____ g/cm^3
12. Dry Density _____ g/cm^3
13. Blows Per Layer _____

NOTES:

EROSION DATA

CROSS-SECTION OF SPECIMEN

U/S _____ mm D/S _____ mm

14. Dish # _____
15. Dish Wt. _____ g
16. Dry Wt. + Mold + Dish _____ g
17. Wt. of Mold + Dish _____ g
18. Wt. of Dry Soil _____ g
19. $\left[\frac{\text{Actual Dry Wt. - Final Dry Wt.}}{\text{Actual Dry Wt.}}\right] \times 100$ _____ %

MOISTURE DATA

Dish No. _____
Wet Soil + Dish _____ g
Dry Soil + Dish _____ g
Wt. of Dish _____ g
Wt. of Water _____ g
Wt. of Dry Soil _____ g
Moisture _____ %

NOTES

Figure K-2. – Pinhole specimen compaction and erosion data.

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Sample _____ Sheet No. 2

BOTTLE NO.	TIME	HEAD ** MM	FLOW RATE			TURBIDITY NTU	CONDUCTANCE μSIEMENS/cm K = @ TEMP °C	PH	NA+ PPM	WATER QUALITY*
			ML	SEC	ML/SEC					

* WATER QUALITY SYMBOLS: C=CLEAR SC=SLIGHTLY CLOUDY CL=CLOUDY D=DARK **HEAD TANK TEMPERATURE:

Figure K-3. – Pinhole test flow rate data.

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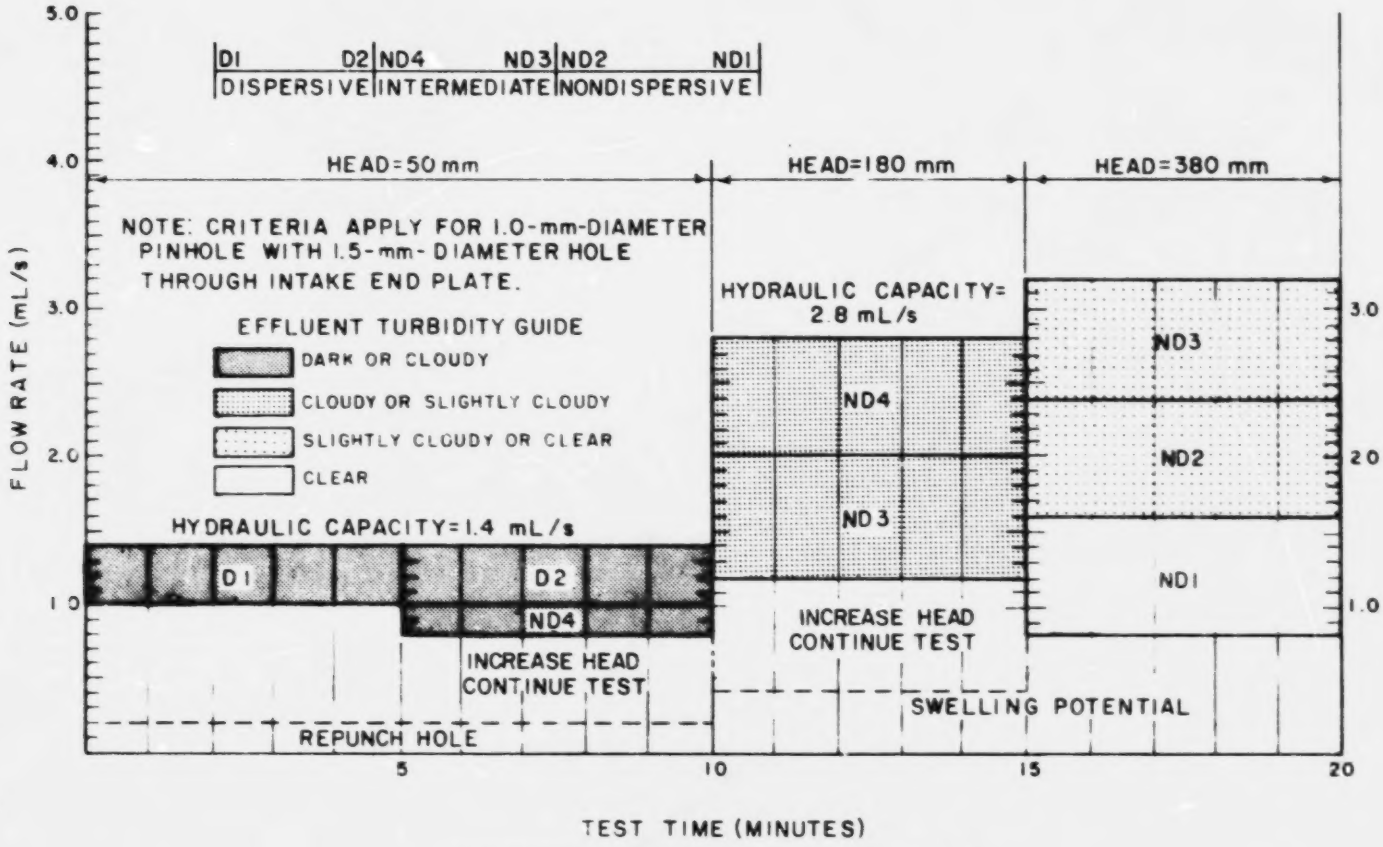


DISPERSIVE GRADE VS FLOW RATE

SAMPLE NUMBER	PLACEMENT CONDITIONS		DISPERSIVE GRADE CLASSIFICATION
	DRY DENSITY	WATER CONTENT	

Figure K-4. – Pinhole test dispersive grade versus flow rate.

PINHOLE TEST

PROJECT Central Arizona Project
FEATURE Tucson Aqueduct - Reach 1
SAMPLE NO. AP-137-TA1 20.0'-25.0'

TESTED BY RPB DATE 8/11/83
COMPUTED BY AP DATE 8/11/83
CHECKED BY RPB DATE 8/11/83

MOLD NO. B VOLUME OF MOLD 21.64 cm^3 WEIGHT OF MOLD 27.8 gms

COMPACTION DATA FOR REMOLDED SPECIMENS

1.	Dry Density (pcf ÷ 0.01602) = g/cm^3	1.854 g/cm^3
2.	Water Content	10.8 %
3.	Initial Dry Wt.	– g
4.	Initial Wet Wt.	40.10 g
5.	Wet Wt. ÷ 5 layers	8.02 g
6.	Wet Wt. + Container 90.1 g (50.00 cm³)	90.1 g
7.	Total Wt. Less Each Layer	
	(1)	82.08 g
	(2)	74.06 g
	(3)	66.04 g
	(4)	58.02 g
	(5)	50.00 g

ACTUAL OBTAINED DENSITY OF REMOLDED OR UNDISTURBED SPECIMEN

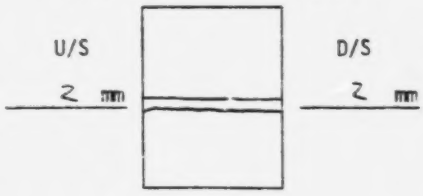
8.	Wet Wt. + Mold	73.10 g
9.	Wt. of Mold	27.8 g
10.	Wt. of Wet Soil	45.3 g
11.	Wet Density	2.094 g/cm^3
12.	Dry Density	1.890 g/cm^3
13.	Blows Per Layer	25

NOTES: Proctor max dry density is 1.951 gm/cm^3
Optimum water content is 12.3 %

EROSION DATA

14.	Dish #	
15.	Dish Wt.	g
16.	Dry Wt. + Mold + Dish	g
17.	Wt. of Mold + Dish	g
18.	Wt. of Dry Soil	g
19.	$\left[\frac{\text{Actual Dry Wt. - Final Dry Wt.}}{\text{Actual Dry Wt.}}\right] \times 100$	%

CROSS-SECTION OF SPECIMEN



MOISTURE DATA

Dish No.	201
Wet Soil + Dish	249.8 g
Dry Soil + Dish	247.2 g
Wt. of Dish	223.0 g
Wt. of Water	2.6 g
Wt. of Dry Soil	24.2 g
Moisture	10.8 %

NOTES
Erosion Data Not Obtained

Figure K-5. – Pinhole specimen compaction and erosion data (typical dispersive soil).

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Sample AP-137-TA1 20.0'-25.0' 8/11/83 Sheet No. 2

BOTTLE NO.	TIME	HEAD ** MM	FLOW RATE ML	SEC	ML/SEC	TURBIDITY NTU	CONDUCTANCE µSIEMENS/cm K=	@ TEMP °C	PH	NA+ PPM	WATER QUALITY*
	1007	50	14	60	0.23	SC					
			20	60	0.33	SC					
			37	60	0.62	SC					
			49	60	0.82	SC					
			61	60	1.02	SC					
			69	60	1.15	SC					
			69	60	1.15	SC					
			69	60	1.15	SC					
			68	60	1.13	SC					
			70	60	1.17	SC					

* WATER QUALITY SYMBOLS: C=CLEAR SC=SLIGHTLY CLOUDY CL=CLOUDY D=DARK

**HEAD TANK TEMPERATURE:

Figure K-6. – Pinhole test flow-rate data (typical dispersive soil).

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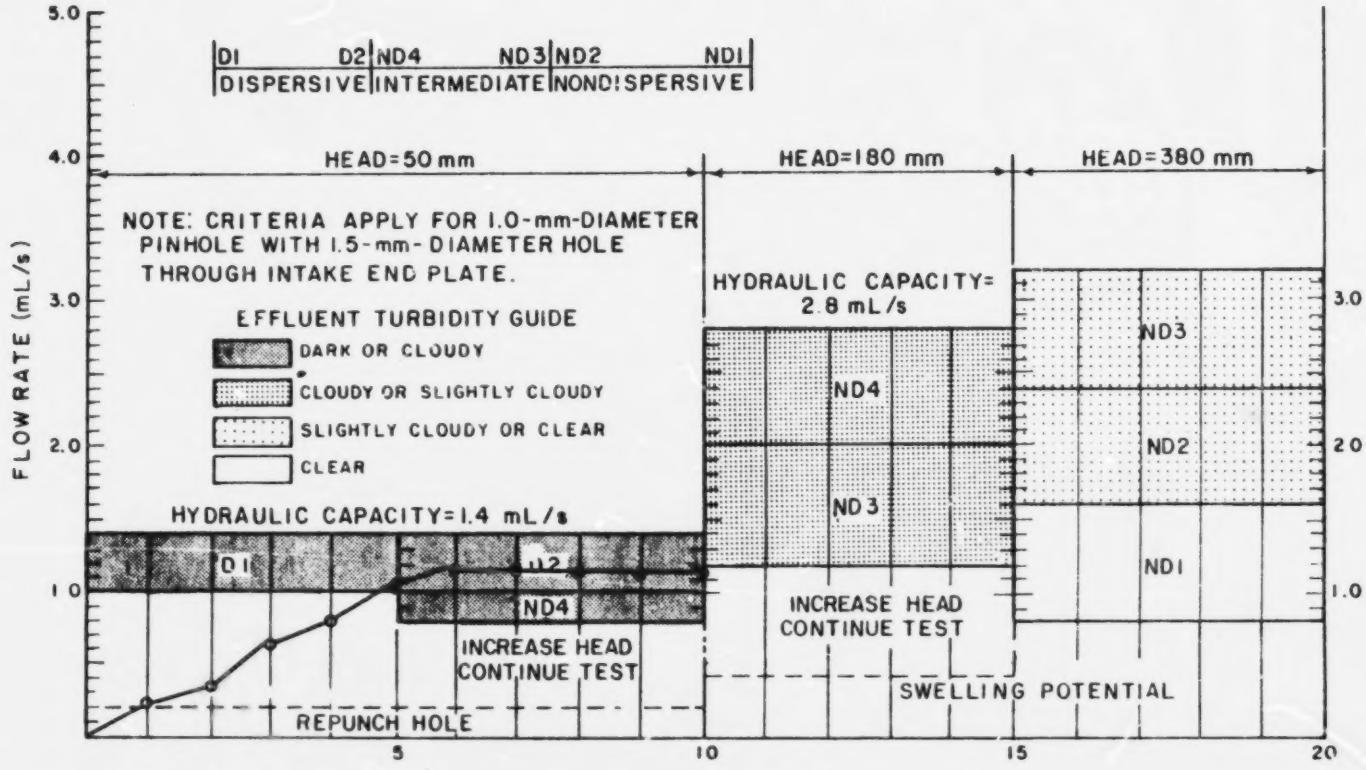

DISPERSIVE GRADE VS FLOW RATE

SAMPLE NUMBER	PLACEMENT CONDITIONS		DISPERSIVE GRADE CLASSIFICATION
	DRY DENSITY	WATER CONTENT	
AP-137-TA1	1.890 gm/cm³	10.8%	D1

Figure K-7. – Pinhole test dispersive grade versus flow rate (typical dispersive soil).

PINHOLE TEST

PROJECT McHue Creek
FEATURE McHue Creek
SAMPLE NO. 56C-199

TESTED BY Kynard
COMPUTED BY Kynard
CHECKED BY Keaton

COMPACTION DATA

MOLD NO. 3 VOLUME OF MOLD 21.58 cm^3 WEIGHT OF MOLD 28.54 gms

1. Dry Density	1.79	g/cm^3
2. Water Content	14.8	%
3. Initial Dry Wt.	38.62	g
4. Initial Wet Wt.	44.35	g
5. Wet Wt. ÷ 5 Layers	8.87	g
6. Wet Wt. + Container 2745g	71.80	g
7. Total Wt. Less Each Layer (1)	62.93	g
(2)	54.06	g
(3)	45.19	g
(4)	36.32	g
(5)	27.45	g

Actual Density After Compaction

8. Wet Wt. + Mold	73.23	g
9. Wt. of Mold	28.54	g
10. Wt. of Wet Soil	44.69	g
11. Wt. of Dry Soil	38.93	g
12. Dry Density	1.80	g/cm^3
13. Blows Per Layer	20	

NOTES:

EROSION DATA

14. Dry Wt. + Mold	67.10	g
15. Wt. of Mold	28.54	g
16. Wt. of Dry Soil	38.56	g
17. [Initial Dry Wt. - Final Dry Wt/Initial Dry Wt.]	.2	%
18. Hole Size	1	mm

MOISTURE DATA

DISH NO.	88	
Wet Soil + Dish	179.7	g
Dry Soil + Dish	177.9	g
Wt. of Dish	139.1	g
Wt. of Water	1.8	g
Wt. of Dry Soil	38.8	g
Moisture	4.6	%

NOTES:

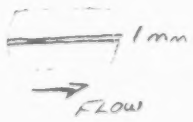

Figure K-8. – Pinhole specimen compaction and erosion data (typical nondispersive soil).

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Sheet No. 2

Sample 56-114

BOTTLE NO.	TIME	HEAD ** MM	FLOW RATE ML	FLOW RATE SEC	FLOW RATE ML/SEC	TURBIDITY NTU	CONDUCTANCE µSIEMENS/cm K=	@ TEMP °C	PH	NA+ PPM	WATER QUALITY*
		50	21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
			21	60	0.35						C
		180	47	60	0.78						C
			50	60	0.83						C
			50	60	0.83						C
			51	60	0.85						C
			51	60	0.85						C

* WATER QUALITY SYMBOLS: C=CLEAR SC=SLIGHTLY CLOUDY CL=CLOUDY D=DARK
**HEAD TANK TEMPERATURE:

Sheet No. 2

Sample 56-117

BOTTLE NO.	TIME	HEAD ** MM	FLOW RATE ML	FLOW RATE SEC	FLOW RATE ML/SEC	TURBIDITY NTU	CONDUCTANCE µSIEMENS/cm K=	@ TEMP °C	PH	NA+ PPM	WATER QUALITY*
		350	86	60	1.4						C
			82	60	1.4						C
			82	60	1.4						C
			82	60	1.4						C
			82	60	1.4						C

* WATER QUALITY SYMBOLS: C=CLEAR SC=SLIGHTLY CLOUDY CL=CLOUDY D=DARK
**HEAD TANK TEMPERATURE:

Figure K-9. – Pinhole test flow-rate data (typical nondispersive soil).

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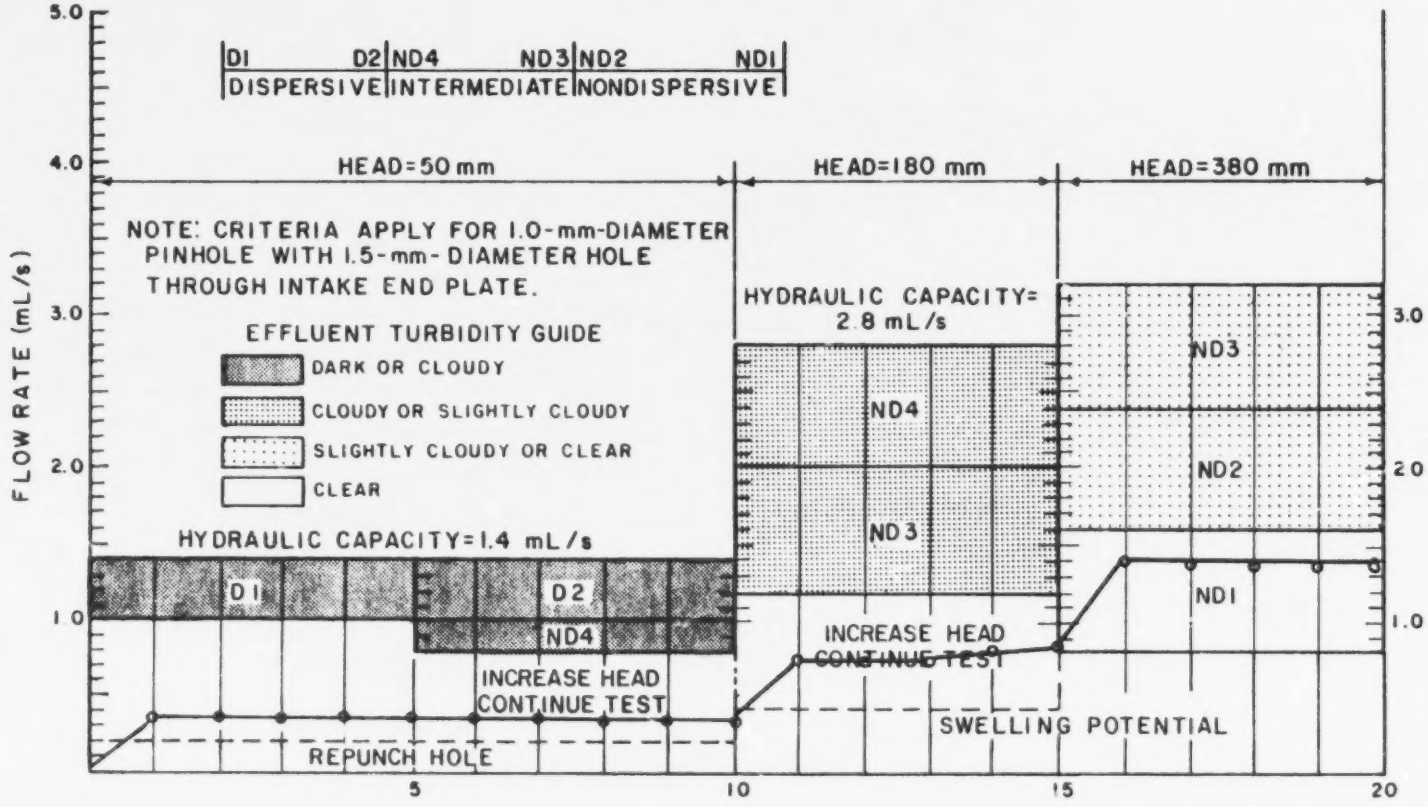

DISPERSIVE GRADE VS FLOW RATE

SAMPLE NUMBER	PLACEMENT CONDITIONS		DISPERSIVE GRADE CLASSIFICATION
	DRY DENSITY	WATER CONTENT	
56C-199	1.80 g/cm^3	14.8%	ND1

Figure K-10. – Pinhole test dispersive grade versus flow rate (typical nondispersive soil).

APPENDIX L

PROCEDURE FOR DETERMINING THE DISPERSIBILITY OF CLAYEY SOILS BY THE CRUMB TEST METHOD

USBR 5400–XX

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CONTENTS

Part		Page
	Introduction	65
1	Scope	65
2	Applicable documents	66
3	Significance and use	66
4	Terminology	66
5	Apparatus	67
6	Precautions	67
7	Sampling, test specimens, and test units	67
8	Calibration and standardization	67
9	Conditioning	67
10	Procedure	68
11	Calculation and interpretation of results	69
12	Report	69
	References	70

FIGURES

Figure		
1	Crumb test (example data sheet)	71
2	Crumb test (blank data sheet)	72
3	Soil crumb specimens and assigned dispersion grades	73

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

USBR 5410. XX *

PROCEDURE FOR

Determining Dispersibility of Clayey Soils by the
Crumb Test Method

INTRODUCTION

This procedure is under the jurisdiction of the Geotechnical Branch, code D-1540, Division of Research and Laborabory Services, Engineering and Research Center, Denver, Colorado. The test procedure is issued under the fixed designation USBR 5400. The number immediately following the designation indicates the year of acceptance or the year of last revision.

This procedure is similar to that outlined in Bureau of Reclamation Report REC-ERC-79-10, except for a rewritten, more detailed description of the procedure photographs of test specimens during the test, and assigned crumb test dispersion grades.

1. Scope

1.1 This designation outlines the procedure for determining the dispersibility of clayey soils by the crumb test method.

1.2 The crumb test has some limitations on its usefulness as an indicator of dispersive clay. A dispersive soil may sometimes give a nondispersive reaction in the crumb test. Soils containing kaolinite with known field dispersion problems have shown nondispersive reactions in the crumb test [1]**. However, if the crumb test indicates dispersion, the soil is probably dispersive.

---

* This test designation is annotated - XX to indicate preliminary issue of yet to be approved test procedure.
** Numbers in brackets indicate references.

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1.3 Ovendried soil should not be used to prepare crumb test specimens, as irreversible changes could occur to the soil pore-water physico-chemistry responsible for dispersion [1].

1.4 Generally, the crumb test should be conducted with the pinhole test and the double hydrometer test, USBR 5405 and 5410, respectively. In cases where the results of the pinhole, crumb, and double hydrometer tests disagee, the general order of reliability should be pinhole, followed by crumb and double hydrometer.

2. Applicable Documents

2.1 USBR 5205, Preparing Representative Soil Samples for Laboratory Use

2.2 USBR 5405, Determining Dispersibility of Clayey Soils by the Double Hydrometer Test Method

2.3 USBR 5410, Determining Dispersibility of Clayey Soils by the Pinhole Test Method

2.4 USBR 9100, List of Laboratory Equipment

3. Significance and Use

3.1 The crumb test provides a simple, quick method for field or laboratory identification of dispersive clay.

3.2 The crumb test, as originally developed by Emerson [2], was called the aggregate coherence test and had seven different categories of soil-water reactions. Sherard [3], later simplified the test by combining some soil-water reactions to use only four categories, or grades of soil dispersion.

3.3 The crumb test has successfully been used as an auxiliary test, with the pinhole test as the primary test, on USBR project feature preliminary invesigations of soil dispersibility. As previously noted in this designation, the crumb test should generally be conducted in conjunction with the pinhole and double hydrometer tests.

4. Terminology

4.1 Dispersive clay - clay coloids that deflocculate in the presence of water because the physico-chemical repulsive forces on the particles exceed the attractive forces. Dispersive clay colloids are easily detached from one another, and the individual particles go into suspension in the presence of water.

4.2 Turbidity - visual cloudiness caused by suspended clay colloids in the water.

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5. Apparatus

5.1 USBR 9100, List of Laboratory Equipment.

5.1.1 Dish, porcelain, evaporating, 300 mL capacity, item 212.

6. Precautions

6.1 Technical precautions

6.1.1 Carefully place the soil crumb specimen in the water directly on the bottom of the porcelain dish when submerging the crumb. Dropping the crumb from the water surface can cause excessive slaking and erroneous interpretation of the dispersion grade.

6.1.2 Do not jar or move the soil specimen and porcelain dish during the test.

6.1.3 Do not use ovendried soil for crumb test specimens.

6.1.4 The use of natural, irregular V-shaped soil crumbs may result in a specimen that is not representative of the total sample. Therefore, select several crumb test specimens to ensure that representative test results are obtained.

7. Sampling, Test Specimens, and Test Units

7.1 Two methods of obtaining test specimens are available:

7.1.1 A cube, 15 mm on each side, is prepared from moist soil passing the No. 4 sieve. Normally, 400 g of minus No. 4 soil are obtained in accordance with the procedures outlined in USBR 5205, Preparing Representative Soil Samples for Laboratory Use. This 400-g representative sample contains enough soil to conduct crumb, pinhole, and double hydrometer tests. The crumb test specimen can be prepared when the 400-g soil sample has been wetted and cured at the water content desired for compacting the pinhole test specimen. As an alternate method, the crumb test specimen can be prepared as a separate specimen by adding water until wetted enough to prepare a coherent 15-mm cube of soil.

7.1.2 A natural, irregular-shaped soil crumb that has not been allowed to air dry is selected. This soil crumb should be approximately the same volume as a cube 15 mm on each side.

8. Calibration and Standardization

8.1 Not applicable - no calibration or standardization required.

9. Conditioning

9.1 Preserve crumb test specimens at field water content or allow specimens to air dry.

9.2 Do not use ovendried soil for crumb test specimens.

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10. Procedure

10.1 Place a 300-mL porcelain evaporating dish near the top portion of the crumb test data sheet with applicable test specimen information noted. See figure 6L-1 for example data sheet and figure 6L-2 for blank data sheet.

10.2 Fill the dish with approximately 250 mL of distilled water.

10.3 Prepare a crumb test specimen by lightly compressing a moist soil sample into a cube 15 mm on each side. Use your thumbs and index fingers to gently form the cube.

NOTE 1. - A natural, irregular-shaped soil specimen may be used in lieu of the specimen described above. For this case, several specimens shold be selected to ensure that test results obtained are representative of the total sample.

10.4 Carefully place the specimen in the water and gently release it only after placing it directly on the bottom of the dish.

10.5 Note and record the time using figure 6L-2.

10.6 As the soil crumb begins to hydrate, observe the tendency for colloidal-sized particles to deflocculate and go into suspension.

NOTE 2. - The colloidal-sized particles are visible in the form of a dense "cloud," or halo, that extends from the soil crumb. The extent and turbidity of the suspended clay particle "cloud" is visually interpreted and is influenced by soil color, i.e., dark soils produce a darker, more distinctly visible cloud.

10.7 Compare the reaction of the soil crumb to the following criteria:

10.7.1 Grade 1. - No reaction - the soil may crumble, slake, diffuse, and spread out, but there is no turbid water created by colloids suspended in the water. All particles settle during the first hour.

10.7.2 Grade 2. - Slight reaction - this is the transition grade. A faint, barely visible colloidal suspension causes turbid water near portions of the soil crumb surface or all around the surface. If the cloud is easily visible, assign grade 3. If the cloud is faintly seen in only one small area, assign grade 1.

10.7.3 Grade 3. - Moderate reaction - an easily visible cloud of suspended clay colloids is seen around all of the outside soil crumb surface. The cloud may extend up to 10 mm away from the soil crumb mass along the bottom of the dish.

10.7.4 Grade 4. - Stong reaction - a dense, profuse cloud of suspended clay colloids is seen around the entire bottom of the dish. Occasionally, the soil crumb dispersion is so extensive that it is difficult to determine the interface of the soil crumb and the colloidal suspension. Often, the colloidal suspension is easily visible on the sides of the dish.

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10.8 Refer to figure 6L-3 for photographs of soil crumb specimens and the assigned dispersion grades.

10.9 Determine and record the soil crumb dispersion grade at 2 minutes, 15 minutes, 1 hour, and 24 hours.

11. Calculation and Interpretation of Results

11.1 Use the following criteria to classify crumb test results:

11.1.1 Grade 1. - Nondispersive

11.1.2 Grade 2. - Intermediate

11.1.3 Grades 3 and 4. - Dispersive

11.2 The 1-hour reading is normally used for the overall test evaluation, if the dispersive grade changed during the test.

12. Report

12.1 Complete figure 6L-2 for all crumb test specimens for one sample.

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REFERENCES

[1] Holmgren, G.C.S., and C. P. Flanagan, "Factors Affecting Spontaneous Dispersion of Soil Materials as Evidenced by the Crumb Test," Proc., ASTM, Symposium on Dispersive Clays, STP 623, Chicago, Illinois, pp. 218-239, 1976.

[2] Emerson, W. W., "A Classification of Soil Aggregates Based on Their Coherence in Water," Australian Journal of Soil Research, vol. 2, pp. 211-217, 1967.

[3] Sherard, J. L., et al., "Identification and Nature of Dispersive Soils," Journal of the Geotechnical Division, ASCE vol. 102, No. GT4, Proc. Paper 12052, pp. 287-301, April 1976.

USRB 5205, Preparing Representative Soil Samples for Laboratory Use
USBR 5405, Determining Dispersibility of Clayey Soils by the Double Hydrometer Test Method
USBR 5410, Determining Dispersibility of Clayey Soils by the Pinhole Test Method
USBR 9100, List of Laboratory Equipment

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CRUMB TEST

LAB INDEX: 36C-107 FEATURE: McGee Creek

BY: Collins DATE: 2-27-81

NATURAL MOISTURE ☒ YES ☐ NO ☐ DISTILLED WATER ADDED

MOISTURE CONTENT 23.4 %

TEST WATER: EC = 21x1 μmho μsiemens/cm, pH = 7.0

WATER TEMPERATURE: INITIAL = 22 °C

3-2-81

SAMPLE NO.	DISH NO.	2 MIN.		15 MIN.		1 HOUR		24 HOURS		COMMENTS INCLUDE EC AND pH
		GRADE	TEMP.	GRADE	TEMP.	GRADE	TEMP.	GRADE	TEMP.	
				3	22°c	3	21°c	4	20.5°c	19x1 μmho pH 7.0

Figure L-1. – Crumb test (example data sheet).

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CRUMB TEST

LAB INDEX: _____ FEATURE: _____

BY: _____ DATE: _____

NATURAL MOISTURE ☐ YES ☐ NO ☐ DISTILLED WATER ADDED

MOISTURE CONTENT _____ %

TEST WATER: EC = _____ μsiemens/cm, pH = _____

WATER TEMPERATURE: INITIAL = _____ °C

SAMPLE NO.	DISH NO.	2 MIN.		15 MIN.		1 HOUR		24 HOURS		COMMENTS INCLUDE EC AND pH
		GRADE	TEMP.	GRADE	TEMP.	GRADE	TEMP.	GRADE	TEMP.	

Figure L-2. – Crumb test (blank data sheet).

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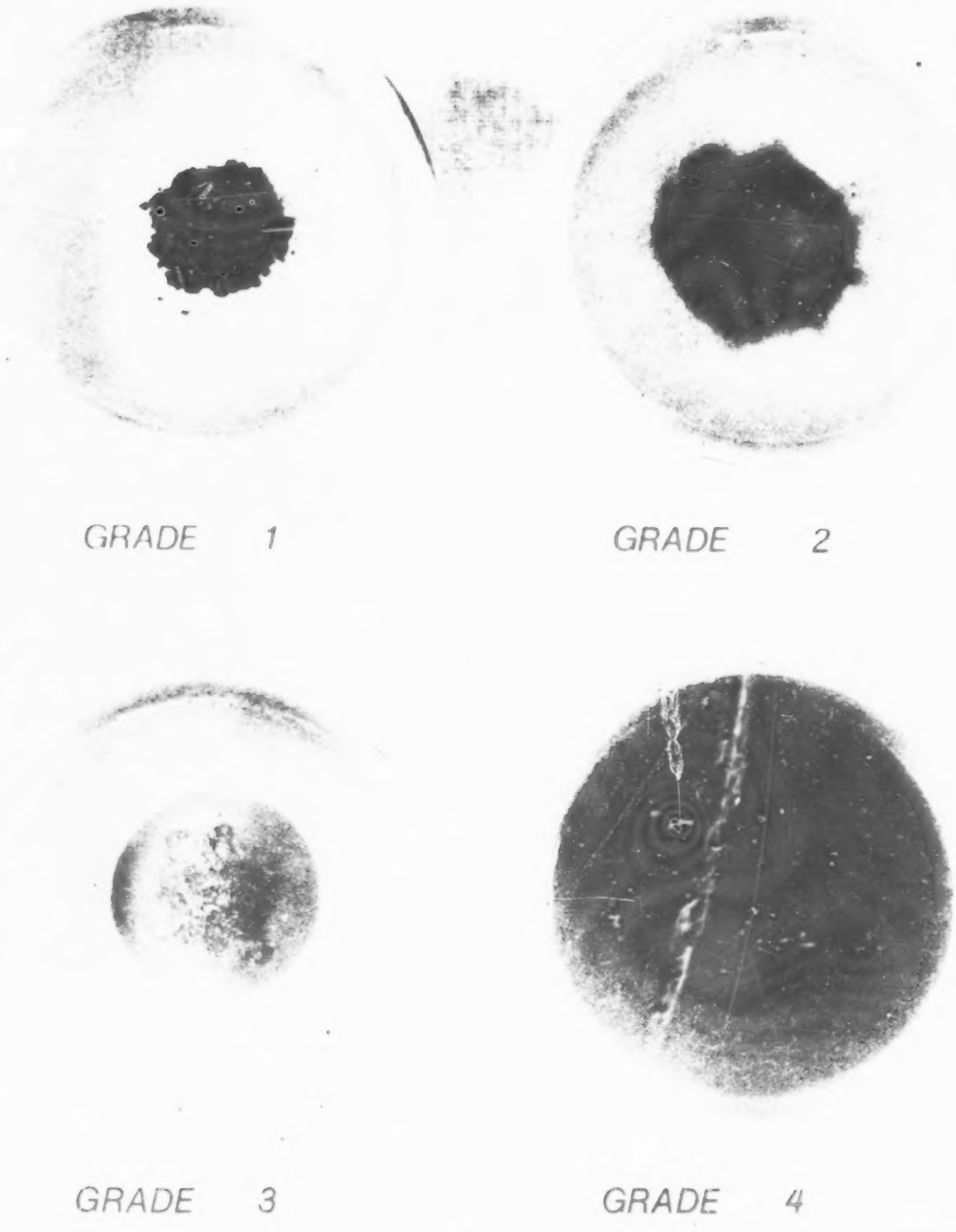

Figure L-3. – Soil crumb specimens and assigned dispersion grades.

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APPENDIX M
FLOW RATE DATA SUMMARIES (ND3, ND2, and ND1 soils) ml/s

Pinhole classification	50 mm head				180 mm head						380 mm head								
	0.00 0.20	0.21 0.40	0.41 0.60	0.61 0.80	0.41 0.60	0.61 0.80	0.81 1.00	1.01 1.10	1.11 1.20	1.21 1.40	0.81 1.00	1.01 1.20	1.21 1.40	1.41 1.60	1.61 1.80	1.81 2.00	2.01 2.20	2.21 2.40	2.41 2.60
ND1		X	X					XX						X	X				
ND1	X	X				XX							XX						
ND1		XX					XX							XX					
ND1		XX					XX						XX						
ND1		XX				XX						XX							
ND1		XX				X	X							XX					
ND1		XX				XX						X	X						
ND1		XX					XX						XX						
ND1		XX					XX						XX						
ND1		XX					XX						XX						
ND1		XX				XX								XX					
ND1		XX					XX							XX					
ND1		XX	XX				XX							XX					
ND1	X	X				XX						XX							
ND1		XX				XX						XX							
ND1		XX					XX						XX						
ND1		XX			X	X					XX								
ND1		XX				XX						XX							
ND1		XX				XX					XX								
ND1		XX				XX							XX						
ND1		XX				XX						XX							
ND1		XX				XX						XX							
ND1		XX				XX							XX						
ND1		XX					XX						XX						
ND1	X	X					XX						XX						
ND1		X	X				XX							XX					
ND1		XX				XX						XX							
ND1		XX				XX					X	X							
ND1		XX					XX							XX					
ND1		XX					XX							XX					
ND1		XX					XX						XX						
ND1		XX					XX						XX						
ND1		XX				XX							XX						
ND1	X	X					XX						XX						
ND1		XX					XX						XX						
ND1		XX					XX						XX						
ND1		XX				XX							XX						
ND1		XX				XX						XX							
ND1		XX					XX						XX						
ND1		XX				XX							XX						
ND1		XX					XX					XX							
ND1		XX				XX							XX						
ND1		XX					XX						XX						
ND1		XX				XX						XX							
ND1		XX					XX						XX						
ND1		XX				XX							XX

APPENDIX M - Continued
FLOW RATE DATA SUMMARIES (ND3, ND2, and ND1 soils) ml/s

Pinhole classification	50 mm head				180 mm head						380 mm head								
	0.00 0.20	0.21 0.40	0.41 0.60	0.61 0.80	0.41 0.60	0.61 0.80	0.81 1.00	1.01 1.10	1.11 1.20	1.21 1.40	0.81 1.00	1.01 1.20	1.21 1.40	1.41 1.60	1.61 1.80	1.81 2.00	2.01 2.20	2.21 2.40	2.41 2.60
ND1		XX					XX							XX					
ND1		XX				XX						XX							
ND1		XX			XX						X	X							
ND1		XX				XX						X	X						
ND1	X	X			X	X						X	X						
ND1		XX				X	X						XX						
ND1		XX				XX						XX							
ND1		X	X			X	X						X	X					
ND1		XX					XX						X	X					
ND1		XX				XX							XX						
ND1		XX				XX							XX						
ND1		XX				XX						XX							
ND1		XX				XX							XX						
ND1	XX						XX							XX					
ND1		XX				XX						XX							
ND1		XX				XX						X	X						
ND1		XX				XX							XX						
ND1		XX				XX							XX						
ND1		XX				XX							XX						
ND1		XX				XX							XX						
ND1		X	X				XX							XX					
ND1		XX			X	X					X	X							
ND1		XX			XX						XX								
ND1	XX						XX							XX					
ND1		XX			XX						XX								
ND1		X	X				XX							XX					
ND1		XX				XX							XX						
ND1		XX				XX						XX							
ND1		XX				X	X							XX					
ND1	XX						XX							XX					
ND1		XX				X	X							XX					
ND1			XX				XX									XX			
MD1			XX					XX								XX			
ND1			X	X				XX											
ND1		XX					XX							XX					
ND1		XX				XX						XX							
ND1		XX			XX							XX							
ND1		XX				XX						XX							
ND1		XX			XX						AX								
ND1		X	X					XX						XX					
ND1			XX				XX							XX					
ND1		XX					XX							XX					
ND1		XX				XX						XX							
ND1		XX				XX						XX							
ND1		XX					X	X											
ND1		XX					X	X											
ND1		XX				XX													
ND1		XX				XX													
ND1		XX				XX													
ND1		XX				XX													
ND1		XX				XX													
ND1	X	X				XX													
ND1		XX				XX							XX						
ND1		XX					XX							XX					
ND1		XX				XX							XX						
ND1	X	X				XX													
ND1		XX				XX							XX						
ND1	X	X				XX													
ND1		XX			X	X					XX								
ND1		XX				XX								XX					
ND1		XX				XX								XX					
ND1		XX				XX													
ND1		XX				X	X							XX					
ND1		XX			X	X							XX						
ND1		XX				XX							XX						
ND1		XX				XX							XX						
ND1		XX				X	X												
ND1		XX				X	X							X	X				
ND1		XX				XX							X	X					
ND1		XX			X	X							XX						
ND1		XX				XX							XX						
ND1		XX				XX							XX						

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APPENDIX M - Continued
FLOW RATE DATA SUMMARIES (ND3, ND2, and ND1 soils) ml/s

Pinhole classification	50 mm head				180 mm head						380 mm head								
	0.00 0.20	0.21 0.40	0.41 0.60	0.61 0.80	0.41 0.60	0.61 0.80	0.81 1.00	1.01 1.10	1.11 1.20	1.21 1.40	0.81 1.00	1.01 1.20	1.21 1.40	1.41 1.60	1.61 1.80	1.81 2.00	2.01 2.20	2.21 2.40	2.41 2.60
ND1		XX				XX						X	X						
ND1		XX				X	X						XX						
ND1	XX				X	X					XX								
ND1	XX					XX					XX								
ND2		XX					X	X							XX				
ND2		XX					XX							XX					
ND2		X	X						XX							XX			
ND2		XX					XX							X	X				
ND2		XX					XX							XX					
ND2		XX					XX								XX				
ND2	X		X						XX							XX			
ND2		X	X				XX												
ND2		X	X						XX							XX			
ND2		XX					XX								XX				
ND2			XX					X	X						X	X			
ND2			XX					X	X						XX				
ND2		XX					XX									XX			
ND2			XX					XX							XX				
ND2		XX					XX								XX				
ND2		XX						XX							XX				
ND2		XX					X		X							XX			
ND2		XX						XX								XX			
ND2		XX							X	X						XX			
ND2		XX							XX						XX				
ND2	X	X						XX								XX			
ND2	X	X					X	X						X	X				
ND3			X	X															
ND3		XX				X		X	X	X						XX			
ND3		X	X																
ND3		X		X						XX									XX
ND3				XX						XX									
ND3		X	X					XX							X				
ND3			XX				XX										X		
ND3	X	X					X												XX
ND3		X	X	X			XX			XX				XX					
ND3		XX					XX							XX					
ND3		XX					XX							XX					
ND3			XX				X		X										
ND3		X	X							XX									
ND3		X	X		X			X	X		X			X					
ND3		XX						X	X										
ND3		X	X				X	X									XX		
ND3		XX						X											
ND3		X	X				X	X											
ND3		XX					XX											X	
ND3	X	X					XX												
ND3		XX					XX												
ND3		X	X			X				X					X		X		
ND3		X	X							XX									
ND3		XX					X		X										
ND3		X	X							XX									
ND3			XX						XX										
ND3		X		X		X		X		XX									
ND3		X		X				XX						XX					
ND3		X		X						XX									
ND3		X	X						X	X									
ND3		X		X						XX									
ND3	XX				X		X			XX							X		X
ND3	X			X						XX									
ND3			XX						XX							X	X		
ND3			XX							XX						X	X		
ND3				XX						XX							XX		
ND3			XX						X	X							X		X
ND3			XX							XX								X	

GPO 847-468

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-922, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.

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